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Air transport of medical supplies by Preighter aircraft in the Covid-19 pandemic

Transport lotniczy materiałów medycznych samolotem Preighter w pandemii COVID-19

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Abstract. Air transport plays a significant role in supply chain cargo. It is used for the carriage of dangerous goods e.g., medical supplies. Its role gained particular importance when the Covid-19 pandemic led to a drastic decline in air operations. In response to the crisis, many air carriers temporarily converted passenger aircraft to preighter aircraft. Due to safety regulations, rising freight prices and easing of restrictions on travel, there is a perceived decline in interest in transporting cargo using such a type of aircraft. The aim of the research was to indicate the role of preighter aircraft in the transport of medical supplies in the Covid-19 pandemic. The research problem was formulated in the form of a question: What conditions made preighter aircraft play a leading role in the transport of medical supplies in the Covid-19 pandemic? The publication adopted the following hypotheses:
1. The participation of preighter aircraft in the Covid-19 pandemic depends on the increase in infections.
2. International and European aviation regulations only regulate guidelines for the carriage of cargo using passenger seats.
3. Due to the specific nature of the transport of Covid-19 vaccines, their safe delivery is guaranteed by thermal shipping container.

The following research methods have been used in the publication: analysis and synthesis, comparison, search of normative acts and literature on the subject, abstraction, and inference. The authors hope the results obtained from the conducted research and the presented considerations will constitute a starting point for further scientific research on the discussed subject.
Keywords: air transport, preighter aircraft, Covid-19, medical supplies, cargo

Abstrakt. Transport lotniczy odgrywa znaczącą rolę w łańcuchu dostaw ładunków. Służy do przewozu towarów niebezpiecznych, np. artykułów medycznych. Jego rola nabrała szczególnego znaczenia, gdy pandemia COVID-19 doprowadziła do drastycznego spadku liczby operacji lotniczych. W odpowiedzi na kryzys wielu przewoźników lotniczych tymczasowo przekształciło samoloty pasażerskie w samoloty preight. Ze względu na przepisy bezpieczeństwa, rosnące ceny frachtu i złagodzenie ograniczeń w podróżowaniu, obserwuje się spadek zainteresowania przewozem ładunków tego typu samolotami.
Celem badań było wskazanie roli samolotów preighter w transporcie zaopatrzenia medycznego w pandemii COVID-19. Problem badawczy został sformułowany w formie pytania: jakie warunki sprawiły, że samoloty preight odgrywają wiodącą rolę w transporcie środków medycznych podczas pandemii COVID-19? W publikacji przyjęto następujące hipotezy:
1. Udział samolotów preighter w pandemii COVID-19 zależy od wzrostu infekcji.
2. Międzynarodowe i europejskie przepisy lotnicze regulują jedynie wytyczne dotyczące przewozu ładunków z wykorzystaniem siedzeń pasażerskich.
3. Ze względu na specyfikę transportu szczepionek COVID-19 ich bezpieczną dostawę gwarantuje termiczny kontener transportowy.
W publikacji zastosowano następujące metody badawcze: analizę i syntezę, porównanie, wyszukiwanie aktów normatywnych i literatury przedmiotu, abstrakcję i wnioskowanie. Autorzy mają nadzieję, że wyniki uzyskane z przeprowadzonych badań oraz przedstawione rozważania będą stanowić punkt wyjścia do dalszych badań naukowych nad omawianą tematyką.
Słowa kluczowe: transport lotniczy, samolot preighter, COVID-19, zaopatrzenie medyczne, cargo

Introduction

The Covid-19 pandemic led to a drastic decline in flight operations and commercial activity, including supply chain cargo disruption. Air carriers such as Air Canada, Delta Air Lines, Emirates, Lufthansa, Qantas and United Airlines have shifted to cargo operations using various strategies. Some have removed seats and other cabin furnishings to increase cargo space, while others have placed cargo on seats to accommodate increased demand for freight operations. It was a response to the bottlenecks caused by the travel restrictions and limitations introduced at the time. Preighter aircraft were thus introduced into the air services market.

The aim of the research was to indicate the role of preighter aircraft in the transport of medical supplies in the Covid-19 pandemic, with particular emphasis on the air transport of Covid-19 vaccines. In order to solve the research problem, the following question was formulated: What conditions made preighter aircraft play a leading role in the transport of medical supplies in the Covid-19 pandemic? Hypotheses were expressed in the assumptions that the participation of preighter aircraft in the Covid-19 pandemic depends on the increase in the number of infections and subsequent waves of the pandemic and on the demand for cargo transportation. International and European aviation regulations only regulate the carriage of

cargo using passenger seats. Due to the specific nature of the transport of Covid-19 vaccines, their safe transport is guaranteed by a thermal shipping container. The publication consists of five main parts subordinated to the research aim. The first refers to the genesis of the term preighter and presents a compact history of the use of these aircrafts in the pandemic, the second is devoted to the characteristics of selected legal acts regulating air transport by preighter aircraft, the third concerns CSB – a new packaging solution for air transport of medical materials, while the fourth focuses on the types and requirements of a thermal shipping container, and the fifth on the requirements related to the safe transport of Covid-19 vaccines.

Literature review

When conducting a critical review of the literature on the subject, it should be noted that its scope, especially of a scientific nature, is limited. On the other hand, most data and information on the pandemic itself, as well as on ways to combat it, are available on official health care websites, pharmaceutical industry infographics, or on health-related websites.

In the case of air transport and transport of dangerous materials by air, such as medical materials, reports, circulars and other legal acts and guidelines of aviation institutions and organizations, such as IATA or EASA, are reliable sources of information. Mention should also be made of such sources of information as the aviation press and internet forums, which tend to target a large audience.

The following paper adopts the definition of the term pandemic suggested by the Australian health clinic Healthdirect Austrialia: "A pandemic is the worldwide spread of a new disease" (…) "A pandemic is not the same as an epidemic. In an epidemic, many more cases of a health condition occur than would normally develop in a community or region, but the condition does not spread further" [11].

The authors hope that their publication may constitute the starting point for further scientific research on the subject of air transport of medical supplies by preighter aircraft in the Covid-19 pandemic.

Preighter aircraft – the new phenomenon in air transport

The term preighter combines two words that describe the type and purpose of an aircraft: passenger and freighter. It was initiated by Carsten Spohr, Chief Executive Officer of the German national air carrier Lufthansa [10]. In this way he defined passenger aircraft, temporarily used exclusively for the carriage of cargo, in baggage holds and, in cases, passenger cabins, with or without seats [7]. Preighter aircraft were initially used to carry medical PPE such as surgical masks and protective suits from China [10]. Figure 1 shows how international cargo traffic has changed over the last three years, considering the three types of aircraft: passenger, freighter and preighter.

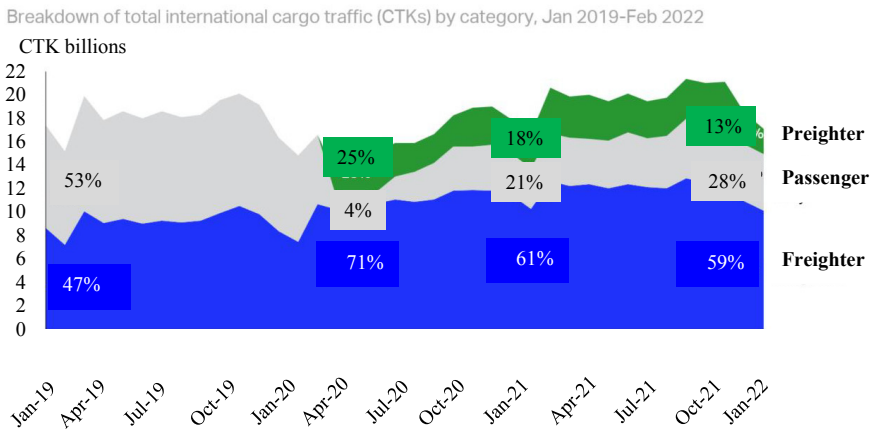


Fig. 1. Breakdown of total international cargo traffic by type of aircraft, Jan 2019-Feb 2022
Source: Based on [7]

As can be seen from the above data before the outbreak of the Covid-19 pandemic, half of the world's cargo was carried in the passenger aircraft belly. By May 2020, their share of the air services market had declined to 4% of international cargo traffic. In response to the decline in demand for passenger travel, air carriers began incorporating preighter aircraft into their fleets, which at the time accounted for 25% of total cargo traffic. With the increase in infections and subsequent waves of the pandemic until January 2022, the percentage of these aircraft fluctuated until travel restrictions and limitations began to gradually ease, with an increase in demand for passenger travel. It started the process of phasing out preighter aircraft in cargo operations. By February 2022, their total share was already only 13%, down five percentage points from the same month last year. An important part of the decline is also due to the seasonal demand for cargo transport, which takes place in late January/early February, during the post-holiday period. Meanwhile, on 31 December 2021, the FAA lifted exemptions allowing air carriers to place cargo in passenger cabins. On 31 July 2022, a similar solution will be applied in the European Union [8].

The requirements of CAAC allow only one group of materials to continue to be executed board passenger aircraft, pandemic control measures. Under current regulations, it is prohibited to remove seats to increase cargo space. The withdrawal of permission for preighter aircraft is due to regulations governing the safe transport of dangerous goods by air, in order to reduce the occurrence of potential risks, such as the risk of fire. In addition, the fire-fighting installation in passenger aircraft is different from that in freighter aircraft and is not designed to extinguish fires of certain cargoes carried. Also, the fact that the screens of the in-flight entertainment system, in the absence of adequate ventilation, can heat up, so it is necessary to supervise the loading of the passenger cabin, by a designated crew member [10].

While preighter aircraft performed well in the early months of the pandemic, they are unlikely to remain a significant factor in global air freight once the pandemic is over. It is estimated that freighter aircraft will continue to carry the majority of air freight, rising to 3260 by 2039, a 60% increase, compared to 2020 [9]. EASA predicts that cargo capacity in passenger aircraft holds will increase by summer 2022, reducing pressure on the supply chain cargo [2]. Freighter aircraft outweigh both passenger and preighter aircraft in freight destinations, high payload capacity, faster transport time, safety regulations and increased payload range [9]. Figure 2 shows the percentage of cargo tonne-kilometres transported by three types of aircraft: passenger, transport and preighter, in 2019-2020, by selected world markets.

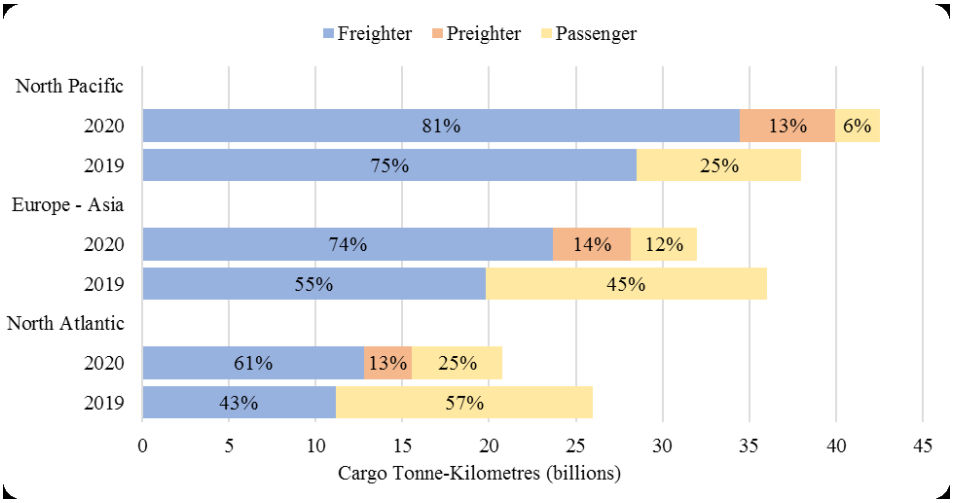


Fig. 2. The percentage of cargo tonne-kilometres transported by three types of aircraft: passenger, transport and preighter for 2019-2020

Source: Based on [7]

Selected International and European legal acts governing air transport by preighter aircraft

As air carriers have shifted towards cargo flights, international and European regulators have introduced regulations for the carriage of cargo in the passenger cabin, while maintaining the existing safety rules, treating it as a key part of the supply chain cargo. IATA, at the request of air carriers seeking guidance on the use of passenger aircraft for the safe transport of cargo and mail, loading cargo in the passenger cabin, has issued *Guidance for the transport of cargo and mail on aircraft configured for the*

carriage of passengers. Its purpose is to provide the means for operators to ensure an acceptable level of safety is maintained at all times for the utilization of aircraft configured for the carriage of passengers for the transport of cargo and/or mail, including loading in the passenger cabin. The above document provides information on the considerations for a safety risk assessment and provides recommendations on the carriage of dangerous goods, including dangerous goods restricted to a cargo aircraft [6]. Table 1 presents applicable cargo configurations for freighter aircraft.

Table 1. Applicable cargo configurations

Cargo type	Passenger cabin					Cargo compartment
	Overhead bin / coat cupboard	Under seat	On the seats		On the cabin floor with nets and/ or straps (seats removed)	
			In cargo seat bags	With nets and/or straps		
Humanitarian supplies/ Medicines	✓	✓	A	A	A and C	✓
General cargo and/ or mail	✓	✓	A	A	A and C	✓
Dangerous goods	X	X	X	X	X	B
Cargo Aircraft (Only dangerous goods)	X	X	X	X	X	D
Where: A – Require NAA approval B – Operators holding a NAA approval to carry dangerous goods as cargo C – Require acceptance by aircraft manufacturer D – Operators holding a national aviation authority approval to carry dangerous goods. Cargo Aircraft (Only dangerous goods) must be loaded into a Class C cargo compartment (not acceptable where passengers are on the aircraft)						

Source: based on [6]

Where an operator has received a specific approval from their national aviation authority to load cargo on passenger seats, they should be loaded using appropriate restraint systems to ensure compliance with all applicable regulatory requirements [6]:

a. Recommend covering all seats with a protective material;
b. The number/type of restraint devices and their attachment points should be capable of restraining the cargo in accordance with applicable certification specifications;

c. Keep the cabin depressurization relief vents unobstructed;
d. All aisles, and access to emergency equipment shall always remain free of obstructions;
e. For twin aisle aircraft, cargo must be loaded so that in each section of the cabin there is a means to cross from one aisle to the other (an empty seat row is considered to provide sufficient access from one aisle to the other).
f. The cargo load shall not extend above the maximum height of the passenger seat in the fully upright position;
g. Always adhere to the loading sequence as reported in LIR. As a rule, for tipping prevention is recommended start to load the cabin from FWD (front) to AFT (back). Unload from AFT (back) to FWD (front);
h. Avoid heavy items and/or shipments with sharp edges;
i. Ensure seatbacks are in the upright position;
j. Position the seat belts behind the seat cushions;
k. Where possible, fold up the inner arm rests;
l. Follow installation instructions provided by bin / CSB manufacturer;
m. Ensure all bins / CSB are properly secured, and straps are latched and tensioned across the seat.

EASA suggests that loading cargo onto passenger seats should be conducted in the following two variations (Figure 3 and Figure 4), with the maximum height of cargo not higher than top of seat backrest [2].

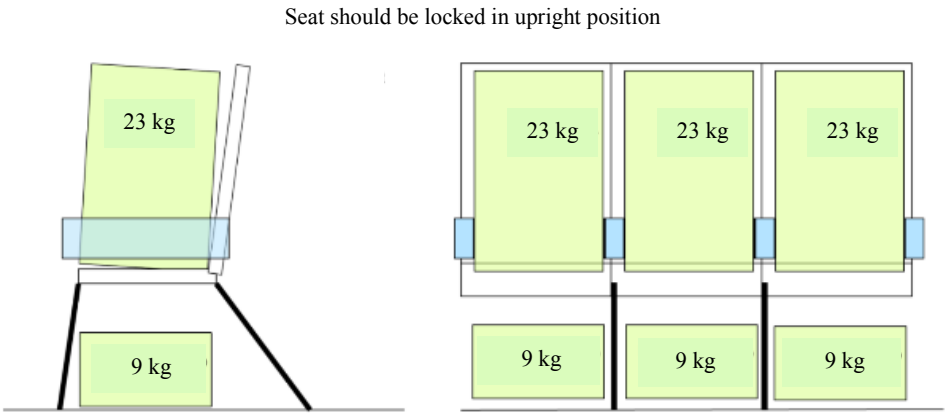


Fig. 3. Interim cargo transportation on seat for three boxes maximum 23 kg
Source: Based on [2]

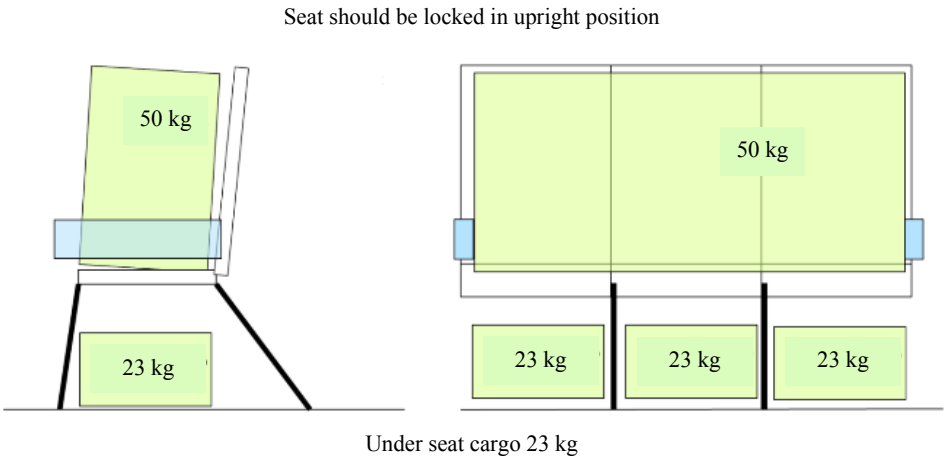


Fig. 4. Interim cargo transportation on seat for one box maximum 50 kg
Source: Based on [2]

CSB – the new packaging solution for air transport medical supplies

Fig. 5. Example of a CSB with a triple-seat variant
Source: [5]

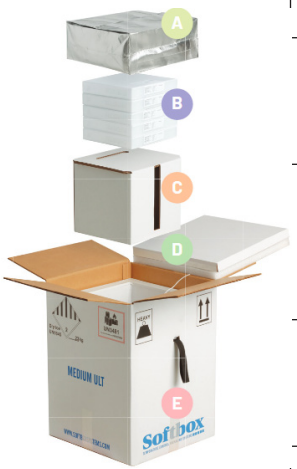
Dutch producer and supplier of air cargo products Trip & Co, in collaboration with logistics operator KLM Cargo, has designed the cargo seat bag (Fig. 5). The product is available in three versions: a single-, double- and triple-seat variant. The bags not only protect the cargo, but also double the load capacity of the seats, thus reducing physical strain during loading/unloading and preventing plastic waste.

Thanks to close cooperation between different KLM departments and between KLM and Trip & Co, the innovative fixed concept has undergone official testing and received approval for implementation. The just-in-time operation meets the need for additional cargo capacity for medical equipment (including personal protective equipment and vaccines). It can also be used on Airbus A330-200, Boeing 777-200, Boeing 777-300 and Boeing 787-10 Dreamliner aircraft [5].

Thermal shipping container – types and requirements

The American pharmaceutical company Pfizer and the German biotechnology company BioNTech have developed a *Guidance for Receiving and Handling the Pfizer-BioNTech COVID-19 mRNA Vaccine (including dry ice procedures)*. Among other things, it contains detailed information on the procedures to be followed after delivery of COMIRNATA, the mRNA vaccine against Covid-19 (with modified nucleosides). Special attention should be paid to the requirements for packaging in dedicated thermal shipping container. There are two types of them: Softbox and AeroSafe, they differ only externally, but their components (Table 2 and Table 3) are similar. Each of them weighs approximately 36,5 kg [3].

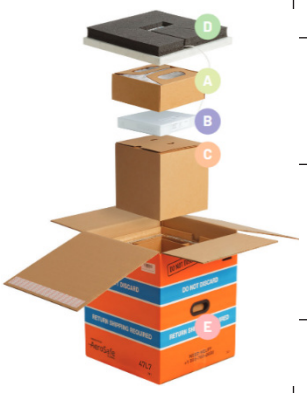
Table 2: Thermal shipping container Softbox and its components



Item	Description
A – Dry ice pod	Holds the top layer of dry ice.
B – Vial trays	Vial trays look like small pizza boxes and contain multiple-dose vials. Each thermal shipping container will have up to five vial trays inside.
C – Box that holds the vial trays	Box within the thermal shipping container that includes the vial trays. The box can be fully removed from the thermal shipping container.
D – Foam lid	Top foam lid that includes an embedded temperature-monitoring device and remains connected to the box.
E – Thermal shipping container	Outer box of the thermal shipping container.

Source: Based on [3]

Table 3. Thermal shipping container AeroSafe and its components



Item	Description
A – Dry ice pod	Holds the top layer of dry ice.
B – Vial trays	Vial trays look like small pizza boxes and contain multiple-dose vials. Each thermal shipping container will have up to five vial trays inside.
C – Box that holds the vial trays	Box within the thermal shipping container that includes the vial trays. The box can be fully removed from the thermal shipping container.
D – Foam lid	The foam lid that can be removed from the AeroSafe thermal shipping container. The temperature-monitoring device embedded in the foam lid.
E – Thermal shipping container	Outer box of the thermal shipping container.

Source: Based on [3]

Safe transport of Covid-19 vaccines – requirements and challenges

The requirements for transporting Covid-19 vaccines are challenging, but the pharmaceutical industry's experience with similar preparations, based on modern technological solutions, guarantees their safe transport. It should be emphasized that the vaccine is particularly sensitive to shocks and vibrations. They can threaten the safety and effectiveness of the preparation. Shocks can also detach particles, reducing its effectiveness, or introduce solid particles, causing adverse reactions. Vibrations, on the other hand, can energize a large, three-dimensional particle and alter its chemical properties [4].

Another problem is the vaccine's sensitivity to temperature, so it needs to be monitored closely. The first batch of Covid-19 vaccines was released quickly. During transport, they had to be kept in a deep-frozen state, i.e., below -60°C, which means packaging and shipping in dry ice [4]. The substance, which can remain cold for up to 72 hours and is classified as a dangerous material according to ICAO, poses a threat to aircrew and ground handlers, which is why it is required that the containers used to transport vaccines are overseen only by specialized staff responsible

for unloading and loading the transported materials. Dry ice also affects the center of gravity of aircraft and, through the sublimation process, reduces its mass, which must be considered during balancing. In addition, thawing vaccines significantly reduces their lifespan and refreezing is prohibited, so alternative means of temperature maintenance must be used [1].

Another aspect is the interrelation between these factors. Each of them may act independently and may lead to damage to the preparation. Therefore, it is necessary to examine those transport operations which may cause a combination of significant vibration, temperature shocks and repeated shocks [4].

Controlling temperature and reducing the risk of vibration and shock throughout the cold chain cargo is therefore particularly important. As mentioned earlier, the pharmaceutical industry's experience with the Ebola hemorrhagic fever outbreak in West Africa, from 2013 to 2016, confirms these proven and effective methods [4].

Each vaccine manufacturer had to demonstrate that they maintained oversight of the entire supply chain cargo to maintain the integrity of the product. In the past, evaluation of vaccine transport was conducted under real-world conditions, placing packages in trucks and aircraft, sending them to different corners of the world. Over time, it has been shown that the type of study has certain limitations. Because of these, it will not be possible to guarantee that the preparation will be subjected to all risks at the same time, nor that the experiment can be repeated under identical conditions [4].

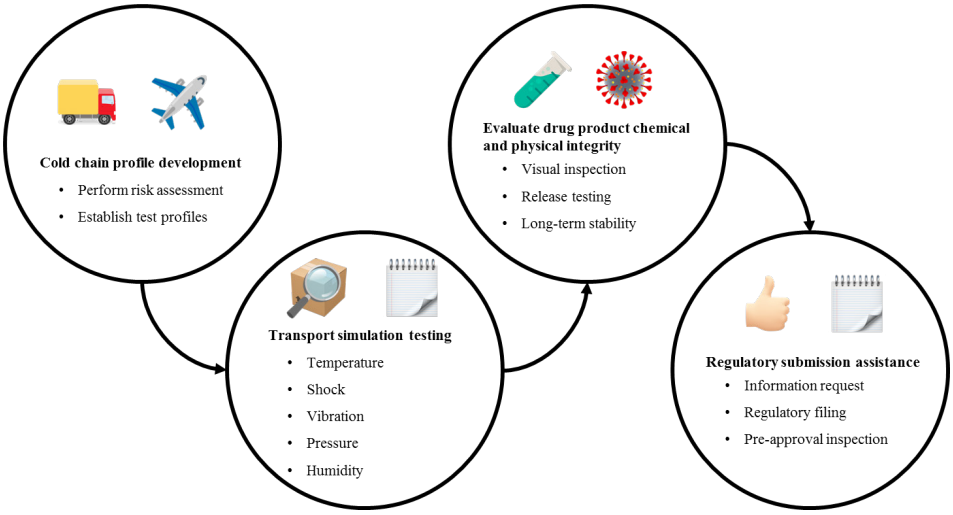


Fig. 6. Controlled transport simulation using cold chain cargo
Source: Based on [4]

Criticism from FDA has spurred the use of more rigorous testing methods. Today, manufacturers of biological drugs, including Covid-19 vaccines, can use simulation methods. These allow the physical and chemical integrity of the formulation to be assessed based on existing and potential risks [4].

Although transportable thermal containers guarantee safe and timely delivery of vaccines, IATA data indicate that 25-30% of preparations are degraded. It can be due to two reasons: a change in chemical or physical stability. These simulation methods make it possible to determine whether and at what point these changes occur, under five hazards: pressure, temperature, vibration, shock and humidity [1]. The Figure 6 presents the controlled transport simulation using cold chain cargo.

Typically, the study begins with a risk assessment to determine the level and seriousness of the risk of the vaccine, which then translates into the design and implementation of the study. Knowledge of transport routes is also essential to verify the actual conditions of transport of the preparation [4].

With the plan developed, a simulation technique can be used, using the five risks mentioned above, under controlled laboratory conditions. It allows data to be obtained that can confirm that the integrity, efficacy and all safety standards of the Covid-19 vaccine will be maintained no matter what happens during transport [4].

Vaccine transport simulation studies are also useful in situations where access to the product is difficult or expensive. Given the scale of the pandemic and the urgent need to stop its spread, every ounce of Covid-19 vaccine is important and cannot be wasted. Assessing controlled transport, where multiple threats are assessed simultaneously, saves the material needed to make the vaccine [4].

In addition to meeting the requirements for the formulation's robustness under emergency conditions, the data obtained from the transport assessment helps determine how the cold chain cargo network will develop. The tests demonstrate whether the vaccine retains its chemical and physical properties after being subjected to the rigors of concurrent threats [4].

If the assessment identifies potential risks in the operational plan, risk mitigation measures should be developed. It is particularly important as if time or resources are not available to change the formulation, changes can be made to packaging, or materials [4].

While the transport plan is approved and accepted by the regulatory authorities, a monitoring and control program must be established to ensure that the vaccine reaches its destination with all safety and efficacy standards. In the preliminary stages of distribution of preparations, control and monitoring will be essential until added stability data is available to confirm the temperature range. These are to confirm the optimal storage temperature and time [4].

Final conclusions

The Covid-19 pandemic caused a crisis in the aviation industry, including disruptions to the supply chain cargo. In response to the situation, many air carriers converted the passenger cabins of aircraft so that medical supplies, especially PPE, protective masks and vaccines could be transported in special thermal shipping container.

The introduction of preighter aircraft in the early stages of the pandemic proved to be a good solution. However, it was a short-term solution. It is confirmed by the statistics on total international cargo traffic from January 2019 to February 2022 presented in the following publication, which indicate that the percentage of these aircraft, in the total number, varied depending on the waves and number of infections.

The noticeable increase in demand for air travel triggered by, among other things, the easing of restrictions and limitations has meant that interest in the transport of medical cargo by preighter aircraft has declined and had to give way to dedicated freighter aircraft. It is these that have a secure future as demand for air freight and cargo continues to grow. Despite optimistic forecasts of a return to normality and a planned 90% of pre-2019 air traffic, it is uncertain how a possible monkeypox flu pandemic, caused by a virus of the genus Orthopoxvirus, will affect the aviation industry.

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ABBREVIATIONS

CAAC – CIVIL AVIATION ADMINISTRATION OF CHINA
CSB – CARGO SEAT BAG
EASA – EUROPEAN UNION AVIATION SAFETY AGENCY
FAA – FEDERAL AVIATION ADMINISTRATION
FDA – FOOD AND DRUG ADMINISTRATION
IATA – INTERNATIONAL AIR TRANSPORT ASSOCIATION
IATA – INTERNATIONAL AIR TRANSPORT ASSOCIATION
ICAO – INTERNATIONAL CIVIL AVIATION ORGANIZATION
LIR – LOADING INSTRUCTION REPORT
NAA – NATIONAL AVIATION AUTHORITY
PPE – PERSONAL PROTECTIVE EQUIPMENT