Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 118 **2023**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2023.118.8

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Kozuba, J., Pila, J., Martinec, F. Analysis of possible modification of transport aircraft to MEDEVAC in the Czech Republic. *Scientific Journal of Silesian University of Technology. Series Transport*. 2023, **118**, 109-121. ISSN: 0209-3324.
DOI: https://doi.org/10.20858/sjsutst.2023.118.8.

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ANALYSIS OF POSSIBLE MODIFICATION OF TRANSPORT AIRCRAFT TO MEDEVAC IN THE CZECH REPUBLIC

Summary. With a growing number of coronavirus patients worldwide, military and civilian transport aircraft are increasingly being used for civilian medical evacuation duties (MEDEVAC) on time-critical flights. This article deals with the possibility of converting an aircraft fleet in the Czech Republic to MEDEVAC. The indication for the analysis of the possibility of transforming transport aircraft was the past and current pandemic situation in the Czech Republic. The main research question is how to implement the modification of a selected airline of the Czech Republic to MEDEVAC. An analysis of the technical data of selected aircraft from Airbus and Boeing was used to investigate this problem. Further, an analysis of the medical equipment required for the MEDEVAC aircraft category was also performed using equipment manufactured in the Czech Republic. The results obtained by the analysis and spatial arrangement of the aircraft deck for the transport of patients with medical equipment confirmed the possibility of such a transformation within the Czech Republic. We consider it important to elaborate on a project that would solve, in detail, all the steps of the conversion of a transport aircraft to MEDEVAC.

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Keywords: aircraft design, MEDEVAC, medical equipment, transport, pandemic

1. INTRODUCTION

Determination of the aircraft is already done during the design process as well as during utilization. The design of the entire aircraft or its cabin compartments is aimed to be as efficient as possible for its operator. Given different needs, the nature of the aircraft can be changed, either purposefully or irreversibly.

In terms of aerodynamic and structural aspects, current airliners and the air medical service aircraft have the same shape as the fuselage cross-section. The shape of the fuselage cross-section is dictated mainly by the strength requirements of the structure (oval, circular, double-bubble or angular) and also inner space utilization.

The only difference between these aircraft is in the equipment of their interior. Aircraft intended for medical purposes have a specific interior layout design given by the manufacturer. Nevertheless, it is possible under certain conditions to transform a conventional airliner into a medical one, that is, change the function of the cabin. Converting an aircraft's design configuration for medical purposes involves several factors. The main factors in the conversion process include the right choice of aircraft, the layout of the cabin (fuselage), the evaluation of the functionality of the cabin and the selection of the right improvements.

Among the most suitable Mid-Size Commercial aircraft whose interior can be converted into a medical interior are the Beech jet 400A, King Air 200, King Air 350, Pilatus, Hawker 800XP, Embraer 600 and others. The conversion analysis must include the necessary medical equipment regarding its weight. The volume of the fuselage is important for the layout of this equipment.

An example of a design change is Delta, which has decided to redesign all its Boeing 777 and 767-400 aircraft. These types of aircraft have enabled Delta to operate on long routes, as the 777-200 LR is one of the longest-range aircraft in the world, allowing Delta to fly non-stop between Atlanta and Johannesburg [1].

Like most of the major changes taking place in airlines around the world, the COVID-19 pandemic has played a key role in decision-making. Delta Chief Operating Officer Gil West explained in a May (2020) statement:

"We are making strategic and cost-effective changes to our fleet to respond to the impact of the COVID-19 pandemic while ensuring that Delta is well placed to recover from the crisis" (1)

In the spring of 2020, airlines were working on how to at least partially exploit current freight needs due to coronavirus.

While passenger transport fell by 90% or more, freight transport, especially from Asia with medical supplies, experienced strong growth in May 2020.

However, airlines have limited options in passenger aircraft because they can place boxes of material in relatively small cargo spaces and on seats without passengers [2].

This paper aims to determine the elements of aircraft design for the needs of the society in the current situation, which is affected by a pandemic (or in any emergency) from the perspective of the customer - the patient. The patient or the wounded can be described as one of the possible types of customers in air transport.

The hypothesis is that emergencies may affect the change of equipment and installation characteristics of the aircraft in the air transport system. Individual countries with a fleet of transport aircraft can convert selected types to become flying hospitals. This article focuses on the analysis of these possibilities in the Czech Republic.

2. AIRCRAFT FUSELAGE CHARACTERISTICS

For a better understanding of the nature of the aircraft, that is, its use in air transport, it is necessary to describe the fuselage and its design (Figure 1). The design of the fuselage is based on payload requirements where either passengers, goods, mail or cargo are transported. The shape of the fuselage is normally determined by the mission of the aircraft. The fuselage is called the central body of the aircraft since it provides the overall structural integrity. From the perspective of interior space, the fuselage can have various uses as described in Figure 1.

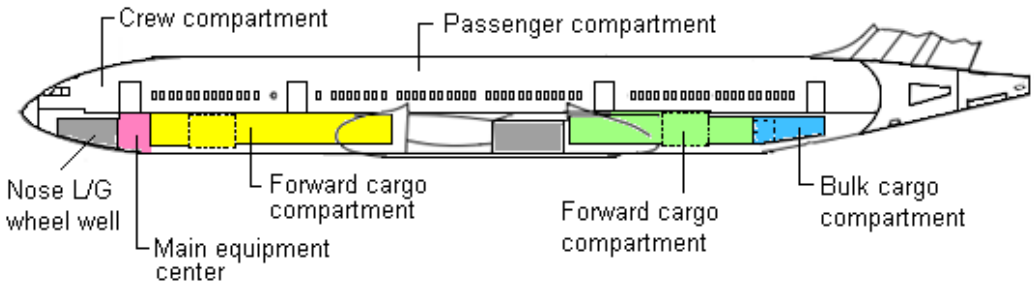

Fig. 1. Typical airliner's fuselage sections

This part of the airframe integrates wings, tail surfaces, and nose landing gear and is used to accommodate the aircraft systems components. The fuselage structure must have high strength and durability and all its interior spaces must be used to the maximum. During the flight, the design of the fuselage must protect against the adverse effects associated with the flight – alternating temperatures, humidity, pressure and noise.

Another cabin aspect is safety as a field that reduces fatalities and injuries resulting from an accident and provides for a safe environment for passengers and crew members in and around the aircraft, before and during boarding and deplaning phases, while the aircraft is on the airport apron with people on configuration, its furnishings, its equipment and its people [3].

A traditional wide-body aircraft typically has a fuselage diameter of 5-6 metres (16-20 feet) with the largest wide-body equipment having a diameter of over 6 metres (20 feet). In the commercial airline world, these are typically twin-aisle aircraft. The largest wide-body aircraft are the Boeing 747 and the Airbus A380. Other wide-bodies configured for GA include the Boeing 777, Boeing 787, Boeing 767, Airbus A330/340, MD-11 and MD-11ER (Table 1).

Larger narrow-body aircraft typically have fuselage diameters of 3 – 4 meters (10-13 feet) and include aircraft the size of, or larger than, a Gulfstream G650. BBJ variants of the Boeing 737, and ACJ versions of the A318/319, are examples of popular large narrow-body aircraft. Other large narrow-bodies in the GA configuration include the Airbus A320-300, Boeing 757-200/300, Boeing 727 and Boeing 737-300/400/500/600/700/800/900ER (Table 2) [4].

Arrangement of wide-body aircraft

All possibilities of arranging wide-body aircraft in a conventional transport aircraft (economy class) are presented in Table 1.

Tab. 1

Arrangement of wide-body aircraft

7 seats in a row	of 160-260 passengers	seats arranged 2-3-2
8 seats in a row	of 250-380 passengers	2-4-2
9 seats in a row	of 350-480 passengers	3-3-3 or 2-4-3
10 seats in a row	of 350-480 passengers	3-4-3

Arrangement of narrow-body aircraft

All possibilities of arranging narrow-body aircraft in a conventional transport aircraft in the economy (tourist) class are presented in Table 2.

Tab. 2

Arrangement of narrow-body airplanes

2 passengers in one row	4–19 passengers
3 passengers in one row	24–45 passengers
4 passengers in one row	44–80 passengers
5 passengers in one row	85–130 passengers
6 passengers in one row	120–295 passengers

3. ANALYSIS OF THE POSSIBILITIES FOR THE TRANSPORT OF THE SICK AND INJURED BY AIR

The first part of the analysis was conducted through interviews with experts from rescue air service on the possibilities of air transport and they provided us with the following interesting information:

1. *"A medical report is required for the transport of each patient, which should then be evaluated by the medical staff and a doctor who will provide medical assistance on board the aircraft to decide whether the patient or passenger is capable of transport at all. The physician should determine if any special equipment is needed before the aircraft is equipped as standard".*
   (Mrs. Denisa Beránková, Aeropartner)

2. *"Based on information from rescue air service, it was found that no truly mass air transport has taken place in the recent history of the Czech Republic. The only similar to this type of transport could be compared to the transport of three soldiers, which took place several years ago, by the air medical service of the Czech Army. Examples of private companies such as Ambulance Meditrans, OK ambulance or Aeropartner were provided with an example for passenger transport.*
   (Dr. Ondřej Franěk, rescue air service")

The Czech Republic army uses government specials (Airbus A-319 CJ aircraft or CASA aircraft) for medical transport. They are used to save the lives of soldiers or civilians in the event of a natural disaster or mass accident, either in the Czech Republic or outside.

4. STATE OF EMERGENCY, AIR TRANSPORT AND THE CZECH REPUBLIC

Another way to change the character of the aircraft is a short-term reconstruction. The moment the aircraft fulfils its purpose, it is rebuilt back to its original form.

Many different types of emergencies can occur anywhere in the world, such as natural disasters, pandemics, environmental or industrial accidents, mass accidents or other dangers that pose a significant threat to the lives of people, property or national security.

In the Czech Republic, we have been dealing with the Covid-19 disease pandemic since last year (2020), which can be described as an emergency with which not only our state is fighting but the whole world, and unfortunately, the end is still not in sight.

Despite all the "weapons", the Czech Republic cannot cope with the disease (February 2021), and the result is overcrowded hospitals and healthcare due to alarming capacity depletion. Because of this, transports had to be carried out, either by the ground rescue service or by the air rescue service. However, these types of transport have only the minimum possible capacity for transport. Several patients also had to be transported to secondary countries.

One example from Slovakia, which transported coronavirus (COVID 19) patients by air to Germany: A spokesperson of the Ministry of Health of the Slovak Republic stated that:
"The fact is that there are few free beds for patients on artificial lung ventilation. We have to think ahead. The situation may worsen unexpectedly. If the number of patients who need the support of artificial lung ventilation increases, we need to have free capacity so that we can hospitalize them immediately," Eliášová added[4]*."*

Example from Italia:
"At the end of March 2020, special passengers arrived in the German city of Cologne on a special flight - six coronavirus patients from Bergamo, Italy, where the situation with COVID-19 was the most difficult in the whole country. They were brought by a special Airbus A310 MedEvac, which has all the necessary medical equipment"[5]*."*

Airbus and Embraer Executive Jets have each separately unveiled their own air ambulance conversion kits, enabling operators to transform passenger aircraft to carry COVID-19 patients in intensive care.

A multi-functional team comprising Airbus Commercial Aircraft, Airbus Defence and Space and Airbus Helicopters proposed the Airbus medical evacuation (MEDEVAC) solution, which is based on the A330/A340 platform.

In a statement, Airbus says the French DGS (Direction Générale de la Santé) actively supported the airframer by providing all the medical specifications associated with COVID-19 patients in intensive care and low care. The work took six weeks.

Czech Airlines j.s.c. (CSA) is the flag carrier of the Czech Republic. It is a modern airline that offers friendly and flexible services. CSA was founded in 1923 and emphasizes safety, quality, experience and tradition. It is one of the oldest airlines in the world. They are members of the global SkyTeam alliance.

However, In the Czech Republic, Czech Airlines, alongside Smartwings, had to lay off around 600 employees due to the COVID-19 pandemic crisis and start implementing several measures.

One of the ways in which CSA's assistance could cope with this crisis could be the possibility of using its fleet to transport the sick and infected to another state.

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[4] https://www.noviny.sk/slovensko/593865-prevoz-pacientov-s-covid-19-do-nemecka-vzbudil-mnozstvo-otazok-ministerstvo-podozrievaju-z-protekcie

[5] https://ekabu.ru/190246-chto-vnutri-samoleta-kotoryy-stal-letayuschim-gospitalem.html

The government has air transport for heads of state and government that can be used for transport; however, their equipment has not been innovated for decades; hence, they would not be able to cope with the needs of the COVID-19 transport.

It is necessary to use the most modern equipment and facilities, especially patient isolation.

The use of the CSA fleet itself would not necessarily serve only in case of the pandemic, but it could be implemented for other types of emergencies that could happen in the Czech Republic, be it political or military attacks, natural disasters, other types of epidemic or pandemic, environmental or industrial accident or mass accident with a large number of injured people.

Conditions for life on Earth are changing and it is difficult to predict what else may affect us in the future.

For possible use, it would be this CSA fleet to the rescue, and it includes three Airbus A320 jets registered with OK-HEU, A319 registered with OK-REQ and Boeing 737-800 registered with OK-TST. This fleet is current as of March 1, 2021.

5. CONVERSION OF THE FUSELAGE COMPARTMENTS OF CSA FLEET AIRCRAFT FOR THE TRANSPORT OF PATIENTS AND PATIENTS WITH COVID-19 IN AN EMERGENCY

In recent cases of infectious diseases caused by highly pathogenic agents (for example, Ebola fever virus, Lassa fever virus, SARS-CoV, MERS-CoV, pandemic influenza virus), which have the potential to spread over several continents within a few days, international health protection authorities took measures – which are, in part, of high economic relevance – to limit the consequences of a possible spread [9].

In the event of an emergency, air transport presents several advantages over land transport by ambulance or helicopter. Among the advantages is the saving of transport time as up to dozens of the sick or wounded can fit on board such a rebuilt aircraft. Aeromedical evacuation (AE) is a challenging process, further complicated when a patient has a highly hazardous communicable disease (HHCD) [8].

Few organizations maintain AE-HLCT (Aeromedical Evacuation High-Level Containment Transport) capabilities, and little is publicly available regarding the practices [10].

In an emergency such as the COVID-19 pandemic, it may be necessary to transport a larger number of patients with the indication COVID-19, as well as patients who would not rule out the disease.

This would mean that seats have to be dismantled on selected aircraft. Rails would be installed here, such as in freight transport.

The whole concept of rebuilding an airplane into a flying hospital is very simple. The whole system works on aircraft seat floor track quick release fitting. Depending on the needs, it is possible to either snap the beds, seats and other medical equipment and furnishing.

Then, it would be necessary to install either deckchairs or PTU (Patient Transport Unit) units on board the aircraft, depending on the possibilities of space on board the aircraft.

PTUs would include:

- four oxygen cylinders with a safety system for venting oxygen overboard through a safety port, if the pressure gets too high,
- defibrillator,
- vital signs monitor,
- transformer for power failure,

- positioning bed with seven-point seat belt attachment and retractable armrests,
- portable breathing apparatus,
- construction for mounting devices,
- suction pump,
- infusion pump and dispenser,
- additional light,
- other medical devices.

In addition, when transporting patients with highly contagious diseases, which also includes the new COVID-19 disease, it is necessary to use special transport and isolation biobags (Figure 2), which until now have been used for transporting patients by helicopter. These are insulating biobags that could easily be attached to loungers or PTUs.

Bio-bag is a highly functional isolation device, tested in practice in the most demanding conditions and is used to transport a person infected with a highly contagious disease or a person to whom it is necessary to ensure protection from the outer environment (typically in case of reduced immunity of the person).

Fig. 2. Bio-bag EBV-30/40 IN/CH [5]

Another option is to place a smaller surgical room on board the aircraft, which would have to be operated in a similar box as the Biobox (medical isolation chamber) – Czech Republic product sold by EGO Zlín (Figure 3), to meet all the hygienic needs of a sterile environment for surgery [6].

Fig. 3. Medical isolation chamber EBX-06 [6]

To operate an aircraft in an emergency, such as transporting infected or sick or injured patients, a trained and experienced team of people is needed to take care of the persons on board the aircraft.

In addition, medical equipment would have to be installed on board the aircraft, including the following:

- loungers with seven-point seat belt attachment and retractable armrests,
- humidifier,
- mobile fan,
- portable vital signs monitor,
- oxygen flow metre,
- inhaler,
- transport incubator,
- set of breathing masks for adults and children,
- thermal insulation blankets,
- suction units,
- blood pressure analyser,
- intubation kits,
- neck brace,
- chest drainage kits,
- backup oxygen bombs,
- vacuum mattresses,
- surgical dressings,
- surgical kits for minor operations,
- wide range of drugs and infusions,
- catheters,
- small medical supplies,
- electrical outlets and a satellite telephone are required.

Another option is to place a smaller surgical room on board the aircraft; its operation would have to take place in a similar box as the Biobox to meet all the hygienic needs of a sterile environment for surgery.

To operate an aircraft in the event of an emergency, such as the transport of the infected, sick or injured patients, a trained, experienced team of people is needed to take care of the persons on board the aircraft.

The team would consist of 2 pilots and an aircraft technician for smooth flight operations.

From a medical perspective, there would be two medical teams, each consisting of two doctors specializing in the necessary field of medicine (in this case, the field of infectious diseases), nurses and paramedics. Dimensions of medical equipment are presented in Table 3.

Tab. 3

Dimensions of the medical devices

Equipment	Length	Width	Height
Biobox	4.84 m	2.12 m	2.10 m
Bio-bag	2.03 m	0.64 m	0.56 m
PTU unit	2.08 m	0.65 m	1.50 m
Folding stretcher	2.01 m	0.55 m	0.17 m
Trolley with stretcher	2.12 m	0.80 m	0.93 m

To give an idea of the arrangement of the Airbus A319 aircraft deck from the CSA airline, a graphic sketch was created according to the actual dimensions of the aircraft, medical equipment and facilities (Figure 4).

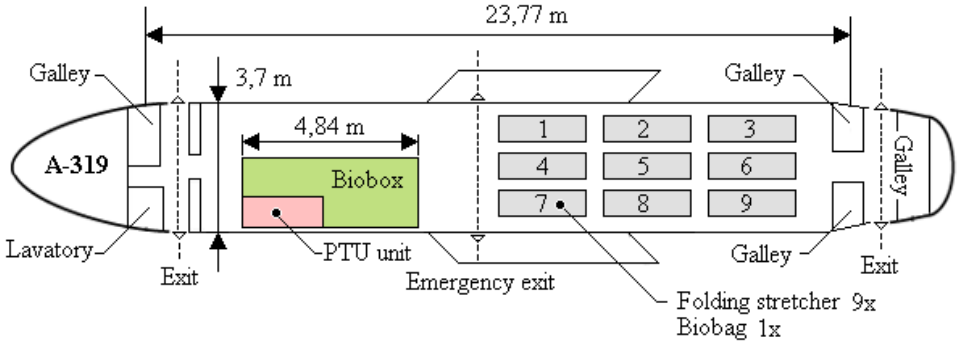

Fig. 4. Airbus A319 - layout design for the MEDEVAC version

On the layout of the aircraft cabin with two exits and one emergency exit (Figure 4), after deducting the already built-up area, the length of the aircraft cabin for use is about 17 m, the cabin width is 3.70 m and the cabin height 2.21 m. Other parameters are in Table 4.

In this space, it would be possible to install in the front part one Biobox measuring 4.84 m x 2.12 m x 2.10 m, in which there would be a PTU unit.

Opposite it, the space could be used for another box with the necessary medical supplies and seats for the medical staff.

At the rear of the aircraft, 9 folding stretchers would be installed, which would be attached to the snap rails, and these beds have a special point attachment for the patient in flight.

Biobags can be attached to the folding bed according to the needs of patients' health.

Tab. 4

Dimensions of the Airbus A319

Length [m]	33.8
Wingspan [m]	34.1 - 35.8
Height [m]	11.8
Wing area [m^2]	122.4
Weight	
Maximum take-off weight [kg]	64 000 - 75 500
Maximum landing weight [kg]	61 000 - 62 500
Operating empty weight [kg]	40 300
Maximum zero fuel weight [kg]	57 000 - 58 500
Maximum payload [kg]	13 200 - 14 000
Standard fuel capacity [litres]	23 860 - 29 840

The second layout or graphic representation of the aircraft deck concerns the Airbus A320 from CSA. The sketch was created based on the actual dimensions of the aircraft, medical equipment and facilities (Figure 5).

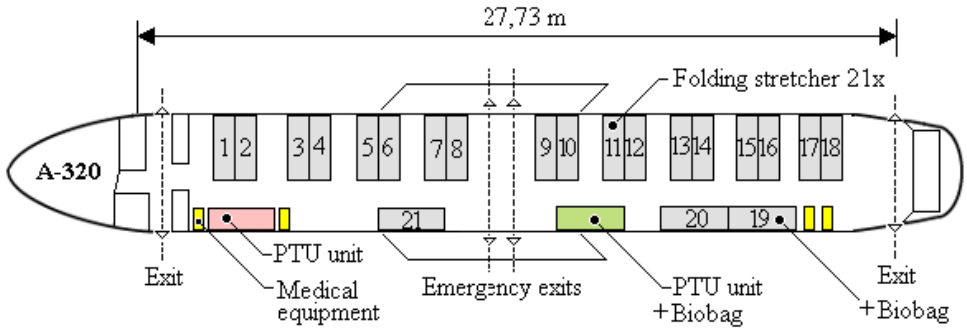

Fig. 5. A-320 layout design for the MEDEVAC version

Compared to the A-319, the Airbus A-320 aircraft has longer cabins, that is, more space for medical equipment and equipment on board. It is possible to use around a 19 m long deck for this aircraft, 3.68 m in width and 2.23 m in height.

In front of the aircraft, the PTU unit is placed with the possibility of a Bio-bag, next to it could be boxes with additional medical supplies. Furthermore, 9 folding beds would be installed in the front part.

The rear of the aircraft could then have one PTU unit with the possibility of a Bio-bag and the rest of the space would fit 12 folding beds.

The space would also have medical boxes with medical supplies and seats for the medical staff at the end of the deck.

The last graphic arrangement focuses on the board of the CSA airline, namely, the Boeing 737-800 aircraft. The sketch was created based on the actual dimensions of the aircraft, medical equipment and facilities (Figure 6).

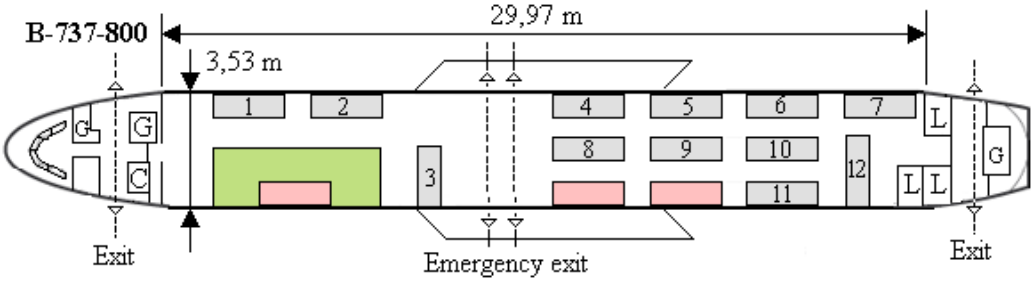

Fig. 6. B-737-800 layout design for the MEDEVAC version

Tab. 5

Dimensions of the B-737-800

Length [m]	39.5
Wingspan [m]	34.3
Height [m]	12.5
Cabin with [m]	3.54

The Boeing 737-800 has the longest deck of the three aircraft in the CSA fleet. Therefore, the use of its deck has more options.

It is possible to use the length of something around 21 m for this aircraft, 3.53 m for width and 2.20 m for the height of the cabin.

The front part of the Boeing is used for the Biobox, which has a PTU unit as a part. Furthermore, 3 folding stretchers could be placed here, around them and the necessary medical equipment would then be placed above them. There would also be seats for the medical team.

At the rear, there would be two PTUs that could be used either alone or with biobags.

The rest of the free space would be used by folding stretchers, which would fit eight. The space would be complemented by boxes for medical supplies.

Tab. 5

Number of medical equipment on board aircraft

Aircraft type	Biobox	Bio-bag	PTU unit	Folding stretcher
Airbus A319	1 x	up to 9 x	1 x	9 x
Airbus A320	0 x	up to 23 x	2 x	21 x
Boeing 737-800	1 x	up to 14 x	3 x	12 x

Table 5 summarizes the number of medical equipment on board CSA aircraft. A fleet consisting of three aircraft was selected for comparison, namely, the Airbus A319 and A320 and the Boeing 737-800.

6. RESULTS AND DISCUSSION

As can be seen, each of the aircraft, depending on its dimensions, can be used for different types of medical equipment and mix. Of course, this form might not be final. From the overall analysis of the possibilities of transporting sick or injured patients, it can be said that in the Czech Republic, there are several options for the method of transport itself.

However, these are only individual patient transports, in the case of the use of private airlines or air rescue service helicopters, as these decks do not have room for more patients.

The Czech Army has aircraft or so-called “government specials” for transporting more people; however, their technology is no longer state-of-the-art and innovated. If needed for situations such as transporting patients with COVID-19, the need to isolate some patients could be a problem.

One solution for such an emergency, such as the COVID-19 pandemic and any other emergency, is the possibility of changing the aircraft's own character to another. An example is a passenger airliner equipped with air ambulance equipment.

This change could occur in the aircraft of the CSA airline, which got into a crisis after the outbreak of the pandemic; however, the state has no need to help it. However, if the state used its fleet for its needs to transport patients from overcrowded hospitals to other states or hospitals across the country, for example, it would help not only CSA airlines but also relieve the health care system in the Czech Republic.

Because of the complex setup involved in air medical evacuation for a highly contagious infectious disease, especially found in repatriation missions that often involve long distances, patients must be optimized before transport. Only patients likely to survive transport will be evacuated. Especially in the case of pulmonary insult, which is predominant in SARS, patients

requiring extracorporeal membrane oxygenation may need to complete therapy before air medical evacuation [11].

7. CONCLUSION

The purpose of a medical evacuation (MEDEVAC) is to allow staff members and eligible dependants the opportunity to secure essential medical care or treatment for a severe illness or injury requiring medical intervention that is locally unavailable or inadequate [7].

MEDEVAC has become commonplace. Aircraft equipped with medical equipment deliver the sick and wounded to inpatient hospitals from remote or hard-to-reach places. If necessary, personnel perform operations or other procedures during the flight.

The flying medical facility allows the patient to receive the same level of intensive care on board the aircraft as in the hospital. It only takes a few hours to turn the plane into a flying hospital.

The patient is attached to a stretcher with a four-point harness like an aircraft pilot wears. The wheeled stretcher can be adjusted so the person can lie down, half sit, or have their legs raised. Medical devices monitor the patient's pulse rate, respiration, blood pressure, and temperature; it also measures the concentration of carbon dioxide in exhaled gases to let the doctors know if they are over- or under-ventilating the patient.

Furthermore, this article focused on the characteristics of aircraft in the air transport system and their unconventional usage. Submitted proposals were prepared based on the current situation in the world affected by the pandemic, which put air transport in an unfavourable position in various areas. The character of the aircraft is already determined during the design and determination of what it will be used for. Therefore, the design itself, whether of the entire aircraft or its cabin, is designed to be as effective as possible for its operators.

The main benefit of this analysis could be the design presented proposals, where the possibility of changing the character of the aircraft in an emergency, with the current CSA fleet, took place.

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Received 13.11.2022; accepted in revised form 21.01.2023