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# INTEGRATION OF TILTROTOR AIRCRAFT INTO MODERN AIR TRANSPORT SYSTEMS

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**Abstract.** The given paper considered the possibility, conditions and outcomes of introducing a tiltrotor aircraft into modern air transport system. The research focused on providing grounds for usage of tiltrotor aircraft at the airports with high level of traffic congestion and at noise pollution. Analysis revealed the future challenges of airport capacity with the increase in forecasted passenger traffic and growing airport congestion. It was suggested to consider implementation of tiltrotor aircraft as an alternative solution to a variety of transportation issues. Efficiency of tiltrotor aircraft was estimated by way of calculating the flight hour cost and compared with the efficiency of the helicopter. High speed of delivery and increased payload are the main assets of the tiltrotor aircraft when contrasted with helicopters. Accessibility concept was regarded as a measure of potential efficiency and sustainability of the project. It can be summarized that the tiltrotor aircraft can serve as a reasonable improvement to the existing network of feeder airports in air taxi or medical service aviation or as corporate means of transport.

**Keywords:** tiltrotor aircraft, accessibility, congestion, air transport system, infrastructure, vertical takeoff and landing airport.

## Introduction

Modern aviation industry faces many challenges. Among them are volatile fuel prices, intramodal competition on part of low cost carriers to traditional airline operators, intermodal competition from high speed transport modes, high rate of revenue defeated by the low operating margin, and of course, the growing demand that needs to be satisfied at the highly congested international airports.

Search for potential alternatives extends from improving the performance characteristics of civil aircraft that are already in operation and restructuring of inefficient airports to the attempts of designing and implementing new aircraft types in air transportation.

When compared to airplanes, tiltrotors help overcome the drawbacks of helicopter technology, i.e. low speed and relatively short distance of flight.

Arrangement of contemporary air transportation is constrained by several issues related with aircraft operation. Choice of the specific aircraft type is an important decision to be made by airline operators. This leads to analysis of airport pairs' capacities. Based on this logic, researchers conducted surveys of the alternatives to conventional civil aircraft applied in scheduled transportation.

The tiltrotor aircraft technology is regarded as a viable competitor for conventional airplanes at urban locations and regional airports that feed large hub airports' with passenger traffic (Boeing Commercial Airplane *et al.* 1987).

In 1990s, tiltrotor aircraft operations for civil aviation were at the initial stage of development. Many constraints came from the public and aviation regulatory bodies. More hindrances emerged from the technology itself, as the safe transfer from the "helicopter" mode to the "airplane" mode requested development of the sophisticated and reliable aircraft control system.

However, with such successful civil tiltrotor aircraft as BA 609 which eventually penetrated the air transportation market, there is no doubt in further adjustment of the existing air transport system to the innovative aircraft technology.

Pursue of tiltrotor incorporation into scheduled air transportation implies another problem of infrastructure development. Entry of a new airplane type into the airport operation requests minimum adjustment of the existing infrastructure. Studies should be conducted of the modifications required in airport infrastructure so as to accommodate civil tiltrotor aircraft. Accessibility of air transport system is another form of infrastructure-related



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measurement that exhibits potential efficiency of tiltrotor commercial operation.

Since some aspects of tiltrotor commercial operation are open to discussion. The given article is intended for disambiguating the matter of tiltrotor drawbacks.

A case study of the prototype civil tiltrotor aircraft CAT-68 provides relevant background for comparing tiltrotor aircraft to helicopter technology.

## Problem Statement

Modern airports are transportation complexes which perform the function of large gateways. At the same time airports produce a diversity of positive and negative impacts. Sustainable development of air transport system dictates that airports control noise, air pollution and land use in order to balance the need of capturing the growing passenger traffic with reduction of the negative effects on the population that resides in the airport vicinity.

Generically, tiltrotors and advanced vertical flight aircraft, such as advanced helicopters, can make a significant contribution to reduction in the current and future system congestion and delays and provide a considerable increase in aircraft and passenger capacity (Boeing Commercial Airplane *et al.* 1987).

The main advantage of tiltrotors is the combination of the high speed of horizontal flight and vertical takeoff and landing. Tiltrotor aircraft has proved to be successful in military aviation, e.g. V-22 Osprey has been effectively performing military missions since 2007 (Bell Helicopter, 2016).

Analysis of the forecasted airport passenger traffic throughput by EUROCONTROL by 2030 showed that one of the negative consequences of the increased volume of air transportation is the considerable growth of the number of airports in Europe (Fig. 1). The airports will work at the limit of their total transfer capacity, which results in delays and traffic congestion.

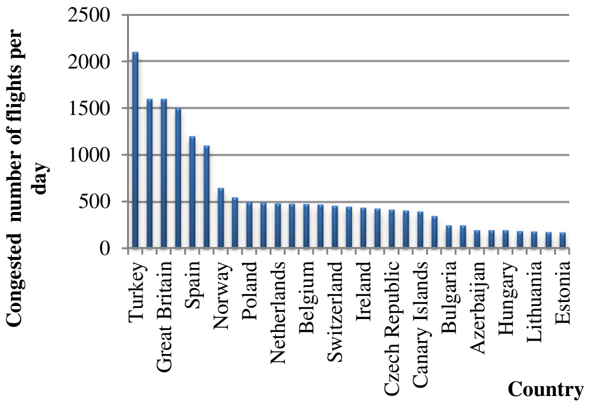


**Fig. 1.** Forecasted daily congestion of flights through European airports by 2030 (Source: EUROCONTROL)

In accordance with the pessimistic scenario, by 2030, European airports will not be able to accommodate over 5 million projected flights. The most congested regions will be Turkey, Germany, Great Britain, Italy, Spain and France.

## Application of tiltrotor aircraft

Based on the GPS (Global Positioning System) data, analysis of the flight distance for European flights by small aircraft was performed. Calculations of the distance between the cities connected by small aircraft were carried out. The results of calculations showed that the flights at the distance of about 150 km were the most frequent and totaled 12% of all small aircraft flights (Rohacs 2006). Approximately 85% of flights were fulfilled over the distance under 500 km, while 3% of flight distances did not exceed 1000 km (Fig. 2). Average distance equaled about 310 km. Hence, turboprop short-haul aircraft appear to be the most popular and common on such connections.

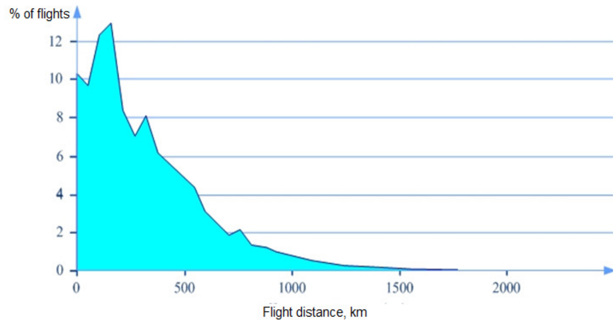


**Fig. 2.** Flight distance distribution of small aircraft flights (Rohacs 2006)

Using the aforementioned evidence, it can be asserted that in the following decade aviation industry will face such problems as:

– significant growth in air traffic;
– decrease of the airport capacity;
– high demand for short and medium-range air transportation (flights up to 1000 km.).

An obvious solution of these problems is development of a safe, efficient and environmentally friendly air transportation system based on the individual (personal) air transport, able to combine the possibility of short takeoff and landing with high speed en-route. Tiltrotor aircraft possesses specific properties that comply with these objectives.

## Efficiency estimation

Tiltrotor allows landing at various airports without taking up parking slots which are limited at the airports in Europe. Fleet of such aircraft could link major airports with regional centers and clear a space for the international flights. It should improve the quality of people's life and provide them with greater freedom of movement. Ideally, tiltrotor aircraft allow sustainable growth of the airport traffic capacity.

Previously, the helicopter was the most familiar aircraft with the capability of vertical takeoff and landing. However, helicopters have never been widely used for scheduled transportation between cities because of low speed and payload limitations.

**Table 1.** The comparison of tiltrotor and helicopter specifications

| Type of aircraft | Efficiency (Endurance) | Max speed (Dash) | Cruise Efficiency (Range) | Downwash/ Temperature | Conversion | Empty Weight | Vibration Environment | Complexity (min number of thrusters) | Yaw control |
|---|---|---|---|---|---|---|---|---|---|
| Helicopter | Best | Low | Lowest | Low | – | Low | Highest | 2 Fixed | Symmetrical |
| Tiltrotor | Good | Good | Good | Moderate | Benign | Increased | Moderate | 2 Vectored | Symmetrical |

A comparison of helicopters and tiltrotors is directly based on the performance and technical parameters (Orchard, Newman 2000).

As it can be concluded from Table 1, the major advantages of tiltrotor are high speed and good cruise efficiency.

Moreover, when compared with helicopter, tiltrotor is less noisy and creates less vibration environment as well as it provides greater cruise altitude ability.

Benign conversion, increased empty weight and 2 vectored thrusters are the drawbacks of tiltrotor technology.

A new tiltrotor aircraft design project entitled CAT-68 was recently launched within the framework of joint Ukrainian-Spanish cooperation (the National Aviation University, Avionicat and G.B. Group Companies).

In order to reveal the efficiency of tiltrotor aircraft CAT-68 and several types of helicopters calculation of cost per flight-hour was performed.

Cost per flight-hour excluding VAT with expected profitability index was determined by the formula (1).

$$C_{f.h.} = S_{f.h.} \times k_p , \tag{1}$$

where $S_{f.h.}$ – cost per flight-hour, UAH / person; $k_p$ – profitability index ($k_p = 1.3$).

Prime cost per flight of tiltrotor CAT-68 is composed of direct and indirect costs and can be calculated as follows:

$$S_{f.h.} = S_{dir.mat.costs} + S_{dir.r.l.} + \\ + S_{gen.prod.costs} + S_{other.dir.costs} + S_{airport} \tag{2}$$

where $S_{dir.mat.costs.}$ – direct material costs; $S_{dir.r.l.}$ – direct costs on remuneration of labor; $S_{gen.prod.costs}$ – general production costs; $S_{otherdir.costs.}$ – other direct costs; $S_{airport}$ – airport costs.

The results of calculations showed that $S_{f.h} = 5556.99$ UAH and $C_{f.h} = 288.96$ USD.

Comparative analysis of tiltrotor aircraft CAT-68 and several types of helicopters in terms of cost per flight-hour is presented in Table 2.

Based on evidence from Table 2, it can be stated that even when taking into consideration airport costs in calculation of cost per flight-hour the tiltrotor aircraft CAT-68 is far more efficient than the analyzed models of helicopters. From the point of view of civil aviation, the key application for the tiltrotor aircraft includes the following domains:

- corporate transport;
- rescue service;
- business aviation;
- individual transport;
- commercial flights;
- tourist transportation;
- express delivery of freight and mail, etc.

**Table 2.** Cost per flight-hour for specific types of helicopters and tiltrotor aircraft CAT-68

| Type of aircraft | Cost per flight-hour, USD |
|---|---|
| CAT-68 | 289 |
| Ka-26 | 350 |
| Mi-2A | 400 |
| BO-105 | 435 |
| AW 109 | 450 |
| Bell 427 | 455 |

Since tiltrotors do not require much space for terminal buildings and runways, small vertiports could be built at accessible locations in urban areas or in places where traditional airports are impossible due to environmental damage or unreasonably high cost. Tiltrotors could perform flights at low altitudes as well as takeoff and landing within metropolitan areas as it is shown in Fig. 3.

**Fig. 3.** Tiltrotor aircraft CAT-68 prototype performing corporate flight within the limits of metropolitan area (Source: SPCUV "Virazh" Unmanned Aviation Center)

## Infrastructure and accessibility impacts

Consideration of infrastructure development to involve operation of tiltrotors for commercial purposes, there can be two different strategies:

1) construction of a heliport for tiltrotors provides reduction of flight delays by 50% (statistical confirmation was obtained in January, 1999, in the Newark International Airport where the decrease of flight delays was

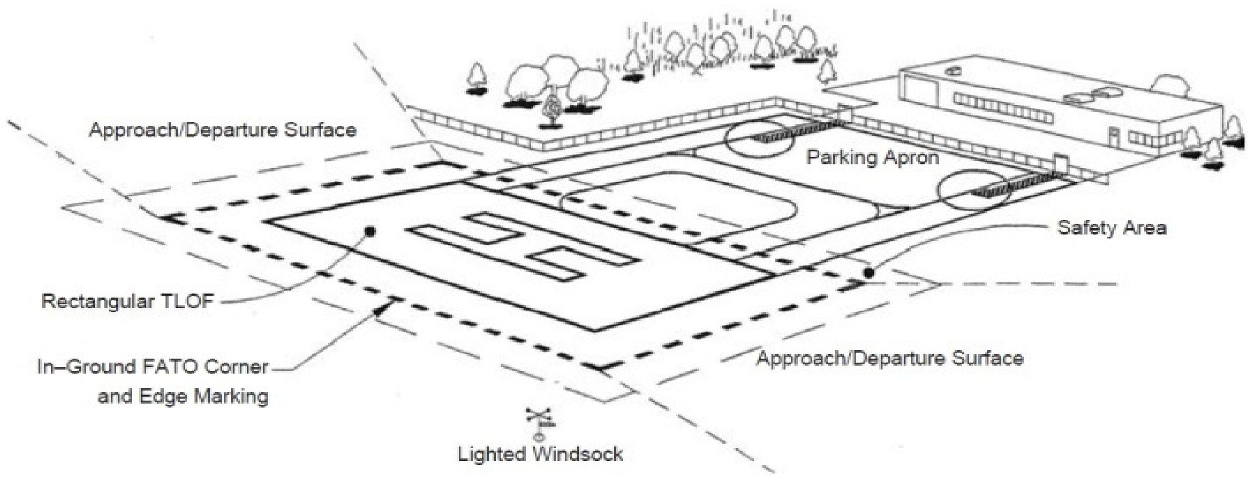


**Fig. 4.** Layout of VTOL airport (Ashford *et al.* 2011)

achieved through bringing into service a heliport instead of building a new runway);

2) amount of initial investment required for construction of heliports is lower than for construction of the new runway at the existing airport, which makes the operation of tiltrotors economically more attractive.

Theoretically, a hertiport requires an area of around 5 acres. It could be located in the vicinity of a city, on the waterfront, rooftops of large buildings or instead of small airports.

According to estimations by the Office of Technology Assessment of Boeing Commercial Airplane Group (1991), each heliport for the tiltrotors could possibly serve about 1 million passengers annually. Such factors as safety, land use, cost of construction, environmental approval, etc. should be taken into account when choosing a possible location for the heliport.

The main facilities for commercial use of VTOL (Vertical Take off and Landing) airport incorporate a parking apron, take off and landing area, taxiways and terminals (Fig. 4). The size of VTOL airport depends on the number of passengers and aircraft to be served.

In some cases, the infrastructure for tiltrotors can eliminate big airport terminals; instead a take off area like heliports can be used. Assuming arrangement of the terminals in the densely populated or industrial areas, tiltrotors could perform quick ‘point-to-point’ transportation over the distance under 800 km. Compared with transportation through large and busy airports, travel time for passengers will be significantly reduced.

Operation of tiltrotors can relieve the problem of environmental pollution and air traffic congestion. The amount of aviation kerosene used by tiltrotors is lower than the fuel burn of conventional aircraft. At the same time, if tiltrotors are operated at large airports, they will not occupy the runway and reduce congestion. Also, negative noise impact on the residents of the airport area where tiltrotors are operated will be lower.

Another important effect of commercial use of tiltrotors is elimination of uneven regional development. Here the opposite concepts of accessibility and peripherality of economic regions arise. Traditionally, transportation needs of the population were solved only by major traffic arteries, along which the population and production capacity of the country were placed.

The solutions for balancing the air transport system demand-capacity components come from different plains. According to one of them, it is expected to develop multilayer complicated transport networks with a vast choice of transportation alternatives for the passengers (Thord 2012).

Tiltrotor technology can create a positive effect on efficiency of conventional air transport systems through: 1) easy integration of its air navigation system into the existent air traffic control system of airports which does not require any additional investment; 2) release of the precious “slots” for conventional aircraft because tiltrotors do not occupy the runway; 3) increase the airport capacity without significant airport restructuring.

The operating cost, passenger cost, and market size conditions of tiltrotor technology were analysed (Hansen 1991). Tiltrotor technology shows better efficiency due to the increasing passenger seat capacity. Overall, the accessibility advantage of tiltrotor enables its economic efficiency even with high costs of operation.

## Conclusions

Based on the evidence from several cited sources, the throughput of the existing air transport systems cannot be improved infinitely and airport congestion resulting in delays will be the typical feature of the major airspace gateways all over the world, especially with the growing population and mobility rate.

There are several advantages of tiltrotor technology which can contribute to the overall increased commercial efficiency of airline and airport operation and thus tiltrotor will improve modern air transport systems.

Comparison of tiltrotor and helicopter specifications using the data from the prototype CAT-68 designed within the framework of joint Ukrainian-Spanish cooperation indicated the substantial economic efficiency of tiltrotors.

Analysis of the relevant infrastructure and accessibility impacts proved that tiltrotor commercial aviation will develop extensively in the following decade.

## References


Ashford, N. J.; Mumayiz, S.; Wright, P. H. 2011. *Airport Engineering: Planning, Design, and Development of 21st Century Airports*. Fourth edition. John Wiley & Sons. 765 p.

Bell Helicopter. Official web-site. Available from Internet: <http://www.bellhelicopter.com/military>.

Boeing Commercial Airplane. 1987. *Civil Tiltrotor Missions and Applications: A research study.* Seattle, WA Boeing Commercial Airplane Co., July. p. 6.

EREA. 2012. *From Air Transport System 2050 Vision to Planning for Research and Innovation.* The Association of European Research Establishments in Aeronautics.48 p.

EUROCONTROL Long-Term Forecast. Flight movements 2010–2030. Available from Internet: <http:// www. eurocontrol.int/STATFOR>.

Hansen, M. 1991. *Assessing Tiltrotor Technology: A Total Logistics Cost Approach.* Transportation Research Board. 14 p.

Office of Technology Assessment, 1991. *Civil Tiltrotor Missions and Applications Phase: The Commercial Passenger Market*, Seattle, WA: Boeing Commercial Airplane Group, 67 p.

Orchard, M. N.; Newman, S. J. 2000. *The compound helicopter versus tiltrotor – Europe's shortcut to the future.* Spitfire Mitchell Memorial Research Scholar, Aeronautics & Astronautics, School of Engineering Sciences, University of Southampton. 11 p.

Rohacs, D. 2006. *Preliminary Analysis of Small Aircraft Traffic Characteristics and its Impact on European ATM Parameters – a Small Aircraft Prediction Model*. Eurocontrol Experimental Centre. 18 p.

SPCUV "Virazh" Unmanned Aviation Center. Available from Internet: <http://www.uav.nau.edu.ua/video_ukr.html>.

Thord, R. 2012. *The Future of Transportation and Communication: Visions and Perspectives from Europe, Japan, and the U.S.A.* Springer Science & Business Media. 265 p.

U.S. Congress, Office of Technology Assessment*, 1991. New Ways: Tiltrotor Aircraft& Magnetically Levitated Vehicles.* OTA-SET-507.Washington, DC: U.S. Government Printing Office. 113 p.