Acta Avionica
Volume XXII, 43–No.2, 2020, DOI: 10.35116/aa.2020.0009

ECONOMIC AND ECOLOGICAL COMPARISON OF AIRSHIP AND OTHER MODES OF TRANSPORT

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Summary. The article deals with the comparison of airship, air, road, rail and ship transportation from the economic and environmental point of view. The economic aspect is represented by calculations of the transport time and the total price for the fuel consumed. The ecological aspect is expressed in terms of the amount of released CO2 into the atmosphere. The comparison is carried out on a selected route, specifically from Brest in France to Hamburg, Germany. These two points were chosen because they are located at a sufficient distance from each other, close to the airport and the port. The model situation does not take into account the various airport, road or other similar transport charges. Only the distance calculated on suitable roads and routes and the fuel consumption of the means of transport during transport are be taken into account.

Keywords: comparison of transport; ecology; economic efficiency

1. INTRODUCTION

Transport is one of the basic attributes that ensures the proper functioning of modern society, the economy and the living standard of people. In addition to the benefits provided by transport systems, its adverse effects such as air pollution, traffic accidents and currently congestion should also be taken into account [1].

Passenger and cargo transport are the most important functions of all transport systems. The individual transport systems are designed to suit passenger or freight transport, but a combination of passenger and freight transport is also used to make the use of means of transport more efficient. Each type of transport is characterized by a set of technical, operational and commercial characteristics. Technical characteristics relate to attributes such as speed, capacity and propulsion technology, while operating characteristics include the environment in which they operate, such as speed limitation, safety conditions or operating hours [2]. This study deals with a comparison of all types of transport, namely air, road, rail, ship and airship, with the aim of evaluating the most efficient mode of transport from the economic and environmental point of view.

Each mode of transport has its key operational and commercial advantages and characteristics. At present, all types of transport are facing increasing demands on capacity, speed, reduced transport costs and, last but not least, reducing environmental burdens.

The choice of the mode of transport, especially in the field of freight transport, is currently a frequently solved problem. Given the economic and environmental pressure, it is necessary to evaluate several parameters when choosing a suitable mode of transport. The choice of the mode of transport depends on several factors, such as the nature of the goods, the available infrastructures, the points of departure and destination, the technology and, in particular, the distance of transport. All these factors together determine transport/shipping costs [3].

Transport costs have a significant impact on the structure of economic activities as well as on international trade. Empirical evidence points out that a 10% increase in transport costs reduces trade volumes by more than 20% and that the general quality of transport infrastructure can be half the variation in transport costs [3].

Currently, many studies address the economic impact of transport on national economies or, at global level, on the international economy and vice versa. Such as studies [4], in which the authors analyze, inter alia, the impact of transport on the national economies of Lithuania, China, Britain, Korea and assess possible ways of developing a sustainable transport system or the effects of paralyzing transport at different times.

Another group of studies address the environmental impact of different modes of transport and how to reduce these negative impacts as the study of [9], which addresses the reduction of environmental burden by including intelligent transport systems, the study [10] presents the characteristics of the simulation model of pro-ecological transport system on the example of Poland.

There are many publications and researches in the field of economic and environmental analyzes. Individual publications mostly deal with the economic and environmental impact in a particular geographical area. Studies comparing the economic and ecological framework on a particular route are less frequent. In this study we focus on freight transport. The novelty of our research is the inclusion of airship transport among the compared modes of transport and evaluation of the economic performance of transport and ecological burden of transport on a particular route. The methods are useful for calculations on any route.

2. BASIC INFORMATION AND PROBLEM FORMULATION

Calculation of economic parameters is focused on fuel consumption on the selected route, because the price of fuel consumed has the greatest impact on the total price of transport. Consumption calculation is focused only on distance travelled, irrespective of any incidental transport charges that cannot be detected. Due to a better comparison between modes of transport, all values are converted into 1 kg of goods transported, because when comparing means of transport with diametrically different carrying capacities, their objective evaluation would not be possible.

Table 1 Comparison of different modes of transport

	ATR 42-500	**Renault Magnum**	**SD-40**	**Airlander 10**	**Panamax**
Distance (km)	1163	1429	1700	1163	1352
Transport time (hours)	2	18	17	8	29
Average speed (km / h)	556	70	100	148	46

(Source: Processed based on information from manufacturers)

Tab. 1 shows the selected means of transport, the length of the route they cover in the carriage of cargo (transport distance), the estimated time of transport, which has been calculated on the basis of the distance and average transport speed shown in the last row. The time and speed of transport are determined under ideal fault-free conditions. Given the fact that it is very difficult to find different modes of transport with similar cost options, commonly used means of transport have been chosen in their transport sectors.

Table 2 Comparison of fuel consumption and load capacity

	ATR 42-500	**Renault Magnum**	**SD-40**	**Airlander 10**	**Panamax**
Distance (km)	1163	1429	1700	1163	1352
Transport time (hours)	2	18	17	8	29
Average speed (km / h)	556	70	100	148	46

(Source: Processed based on information from manufacturers)

In Table 2, it can be seen that individual modes of transport differ substantially from each other, which causes some problems in comparing their transport costs and their environmental burden. We have calculated fuel consumption by kilograms for all selected means of transport, so that in the

following calculations we can better calculate how much fuel the transport mean consumes per kilogram of freight transported.

3. CALCULATION OF THE AMOUNT OF RELEASED CO_2

The calculation of the amount of CO_2 released during transport into the atmosphere is based on the amount of fuel consumed during the journey. For the amount of CO_2 released into the atmosphere, it is necessary to know the composition of used fuels first. In the calculation, two fuel types are considered, namely conventional diesel, which is used by most of the transport means being compared and kerosene, kerosene, which only uses the ATR 42-500 aircraft. The percentage of the individual elements of which the selected fuels are composed is shown in the following table.

Table 3 Fuel composition

	Diesel	**Kerosene**
C	86,36	86,21
H	12,11	13,77
O	0,44	0
S	0,02	0,02
Remainder	1,07	0
	100	100

(Source: [10])

Subsequently, according to the values in Table 3, it is necessary to calculate the amount of air necessary for complete combustion of fuel to CO_2 and H_2O. The amount of air required is calculated according to the following formulas [12], [13]:

Calculating the minimum volume of oxygen

$$V_{O_2 min} = 1{,}8643C + 5{,}555H + 0{,}6985S + 0{,}6997O \tag{1}$$

The minimum volume of dry air

$$V_{VSmin} = \frac{V_{O_2 min}}{0{,}21} \tag{2}$$

Calculation of CO_2 quantity

$$V_{CO_2} = \frac{22{,}263}{12{,}011} C + 0{,}0003 \times V_{VSmin} \tag{3}$$

Calculation of SO_2 quantity

$$V_{SO_2} = \frac{21{,}891}{32{,}06} S \tag{4}$$

Table 4 shows the amount of CO_2 and SO_2 produced per kilogram of fuel burned at a given air consumption. Given the fact that the values for SO_2 came out at minimum level, in the following calculations we considered only the released amount of carbon dioxide CO_2, by means of which we compared the environmental impact of the selected means of transport on the air.

Table 4 Emission

	Diesel	**Kerosene**
The minimum volume of oxygen (m^3/kg)	2,28	2,37
The minimum volume of dry air (m^3/kg)	10,86	11,29
CO_2 volume per 1kg of fuel (m^3/kg)	1,60	1,60
SO_2 volume per 1kg of fuel (m^3/kg)	0,013656	0,0136656

The compared fuels have only a slight difference in the individual data, so their composition is very similar. In Table 4 we can also see the amount of SO_2 produced by burning one kilogram of the fuel, which, however, is negligible compared to CO_2, so we have not considered it further.
However, the results do not have a high informative value, because each mean of transport had a different freight capacity, therefore it is necessary to recalculate the amount of CO_2 produced per kilogram of freight, which we later corrected by conversion to unit rate and thus per kilogram of freight.

4. CALCULATION OF TOTAL ECONOMIC AND ECOLOGICAL INDICATORS

The table below shows that the most economical and environmentally friendly mode of transport/per kg of cargo is ship transport, but the transport time is the longest. The second most environmentally friendly way was road transport, which, however, already produces several times more CO_2, followed by train and airship with similar results. The aircraft, although it has covered this distance in the shortest time, has released the most pollutants into the air. If the route was shorter, or if cargo had to be transported to hard-to-reach places, the airship would be the most economical and fastest option. Thanks to the opportunity to move in the air and thus avoid difficult airways, and unlike an aircraft, it is not tied to fixed runways.

Table 5 Emissions and fuel prices

	ATR 42-500	**Renault Magnum**	**SD-40**	**Airlander 10**	**Ship**
Emission (m^3)	2049,86	582,4	13613,6	716,72	427266,67
Emission per 1kg load (m^3)	0,3761	0,0224	0,0648	0,0717	0,0082
Fuel price (€)	795,60	299,21	6993,99	368,21	219508,25
Fuel price per 1kg load (€)	0,1459	0,0115	0,0333	0,0368	0,0042

(Source: Processed according to [15])

5. CONCLUSION

However, the current demand is influenced by integrated transport systems whose flexibility is given by the combination of individual types of transport on selected sections of the route. Different modes of transport can compete or complement each other on specific routes in terms of cost, speed, availability, frequency, safety, comfort, ecology, etc. [2].

Based on the results, it was found that the best mode of transport is the combination of individual types/modes of transport, given the distance, the route and the time at which we need to transport it to the final destination. Air transport has been assessed as the least environmentally friendly and economical, but still the most used transport mode for long-distance transport and for transport of goods that need to be transported in a short time, because that is its dominant advantage. Airship transport is in terms of speed closest to air travel, although it is slower. According to the manufacturers, the consumption of Airlander 10 represents approximately 20 to 40% of the consumption of a conventional aircraft, which is worth considering.

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Received 12, 2019, accepted 12, 2020