ECONOMIC ANALYSIS OF THE LIFE CYCLE OF TRANSPORT AIRCRAFT FOR REGIONAL TRANSPORT

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The work deals with the economic life-cycle analysis of a regional transport aircraft. It shows the cost and theoretical basis of their assessment for the life-cycle. It deals in details with the economic analysis of costs for a planned life-cycle of the aircraft. In analyzes the costs associated with the operation of such aircraft. And finally, is devoted to economic analysis of costs associated with maintenance and repair of the aircraft.

K e y w o r d s: analysis, costs, economic analysis of the operating costs of the aircraft, life-cycle of the aircraft, aircraft maintenance, aircraft repair

1 INTRODUCTION

When deciding to purchase the selected type of an aircraft, it is not sufficient to evaluate only the technical parameters such as desired range, speed, take-off and landing length, number of passengers, fuel consumption etc., but it is important to select from an appropriate number of aircraft types the one which will have a total cost of the life-cycle the lowest. All of this should be the result of the economic analysis that should be available to the future owner of the aircraft. The analysis should be independent, because the manufacturer wants to sell the aircraft at any cost, only fails to show some data, for example the engine.

2 THEORETICAL BACKGROUND OF THE PROBLEM

This problem has been applied to the selected aircraft type L 410, with which there is long-term experience. There are statistics available, therefore this type is the most suitable. The methodology is based on literature sources and is standard used in aviation.

Airplane L 410 UVP-E20/L 420 is the latest and most advanced successor to the famous series L 410, is well known and world-renowned 19 seats turboprop airplane with excellent technical characteristics, high operational reliability, easy handling and maintenance. It has been produced for more than thirty years. It is successful mainly because of its safe operation. It serves reliably in a wide range of climatic conditions around the world. With its rugged, durable design it can withstand extreme climatic conditions ranging from -50°C to + 50°C and thus offers exceptional performance both in terms of the Sahara desert, or as in the Siberian tundra. The unique chassis design allows the airplane to land almost anywhere, it only needs only a few hundred meters of the landing area of the minimum load 6 kg/cm^2 (85 lm/m^2), so it is able to land and take off the rain soaked lawn.

Airplanes L 410/L 420 simply represent an ideal combination of world-class technical and economic parameters of operation for passenger travel on short and medium distances [1, 2, 3, 4].

2.1 The economic cost

Business expenses are divided into three basic groups:

1. Costs that is directly dependent on the execution of the flight by the aircraft on a particular route. It includes:
   a) Fuel consumption.
   b) Premiums for the flying personnel.
   c) Maintenance of the aircraft, normal and medium aircraft repairs, overhauls etc...
   d) Diets for the flying personnel.
   e) Ground service for passengers.
   f) Check-in, parking and landing fees.
   g) Aircraft leasing.
   h) Services on board.
   i) Other.
2. Fixed costs which do not depend on the flight and are constant. They include:
   a) Basic salaries of the flying personnel.
   b) Depreciation of aircraft and engines.
   c) Aircraft insurance.
   d) Contribution to social security.
   e) Other.
3. Common costs arising from the very existence of the enterprise and the system ensuring the company’s main activity. These include:
   a) Administrative business expenses.
   b) Total transport costs [6].

2.2 Calculating the economic cost of air transport

For the costing of the following components and transport prices and transport performance in aviation and aerial work there is a branch formula designated.

A business calculation formula consists of:

DIRECT COSTS:

1. Fuels.
2. Direct material.
3. Direct wages.
4. Depreciation of the aircraft.
5. Repair and maintenance of the aircraft.
   - 5.1 direct material,
   - 5.2 direct wages,
   - 5.3 contribution to social security,
   - 5.4 other costs for repair and maintenance of aircraft.
6. Other direct costs.
   - 6.1 contribution to social security,
   - 6.2 travel expenses,
   - 6.3 airport and navigation costs,
   - 6.4 other direct costs.
7. Operational expenses.

OWN OPERATIONAL COSTS:

8. Corporate social consumption costs.
9. Administrative expenses.

FULL OWN COSTS OF THE OUTPUT:

10. Subdelivery.
11. Profit (loss) [6].

2.3 Theoretical basis of assessment of life cycle costs

Evaluation of life-cycle costs is a complex dynamic process that forms the basis in deciding each life-cycle stages. Currently in many countries it is not possible to perform an acquisition without an in-depth analysis and cost estimate. This approach is used primarily by government agencies and departments where the cost of acquisition represents hundreds of millions of dollars. An investor in such a large investment seeks answers to the following questions:

- what will the costs of operating / maintenance of the system be,
- how long will the system be operating [5].

To conduct a comprehensive analysis and cost estimate it is needed:

- to identify all relevant activities throughout the life-cycle, which will generate cost,
- to identify factors to be considered as a measure of efficiency,
- to develop a costing structure for the entire period of anticipated use and ensure that all relevant prices are added only once,
- to develop a degree of efficiency in order to be able to compare various alternatives,
- to identify and determine the major item costs,
- to use the item costs and the degree of efficiency to determine the most suitable decision [5].

The contracting authority in his own interest shall obtain the information specifying the mode of operation and related costs. The required data should include at least the following basic information:

- the average hourly fuel consumption or specific consumption (consumption calculated in units of power),
- the average hourly consumption of other working fluids and gases,
- maintenance of various degrees , list of works and preparation,
- a list of all parts with a limited period of use, their life or their technical life between repairs and the cost of their acquisition at the end of their technical life or repair costs,
- a list of the necessary controlling and measuring equipment, either commercial or special,
- proven reliability tests specified by the probability of failure,
- the determination of the average costs to remove defects calculated in hours worked (or other indicator of reference indicating activity – landing cycles, engine hours, mileage) between two consecutive failure,
- the likelihood of an upgrade with the determination of the likely timescale and the likely cost,
- servicing requirements – education and training [5].

3 ECONOMIC ANALYSES

Analysis was performed on the above-mentioned airplane L 410. All reported data are fictional. In order to determine the individual costs one must establish the following data:

Table 1. Input data

Purchase price L 410	1 350 000 €
Life of the aircraft	12 000 flying hours 6 000 landings 20 years
Annual utilization of the airplane	600 flying hours The average duration of the flight – 2 hours 300 landings

To establish the economic efficiency of a transport aircraft, it is necessary to know its operating costs.

3.1 Direct costs

Direct costs of operating an aircraft can be divided into five groups:

1. The cost of salaries of the flying and service attendants.
2. The cost of fuel and lubricating materials.
3. The cost of depreciation and maintenance of the airframe equipment.
4. The cost of depreciation and maintenance of the engine.
5. Airport charges.

3.2 The cost of premiums of the flying and servicing attendants

The cost of a salary attributable to an air hour depends on the number of crew, type of the aircraft and hours flown by the crew, it also depends on the line type and the flight conditions. The cost of the crew pay may be determined by the unit cost down to one crew member (ß3 and ß4). Hourly wage costs for staff are in an average of one member of the flying staff without service staff, and separately for one member of the servicing staff depending on the take-off weight and annual flying hours for the crew. The unit cost is set at mid-raid of 550 hours per year for the crew [6].

The cost of the flight crew pay is calculated by the formula:

$$N_{pos} = n_{lp} \; x \; ß_3 + n_{op} x \, ß_4 \qquad (1)$$

Where:

$ß_3$ – unit cost of flying personnel salary in € per person per flight hour

$ß_4$ – unit cost of servicing personnel in € per person per flight hour

n_{1p} – number of flying personnel

n_{op} – number of servicing personnel

3.3 Fuel costs

3.3.1 Energy intensity

Transport is one of the sectors of economy the most demanding of fuel – energy resources. Currently there is a reassessment of the situation of stocks of fuel. In traffic petroleum fuels are used, which stock are not inexhaustible. At present the biggest requirement is to get low energy consumption and use of available energy resources at reasonable prices, while in the past, speed and capacity was critical in transport [6].

Reducing energy and fuel consumption can be carried out in several ways:

- by Limiting traffic,
- by reducing transport demand,
- by the optimal division of labour according to:
  a) Benefit for the type of transport.
  b) Distance.
  c) Claim for speed.
  d) Safety, etc.

3.3.2 Fuel consumption

There is:

- The median hourly consumption ($Q_{med.h}$)
- Mileage consumption (g)
- Mileage-ton consumption

The median hourly fuel consumption ($Q_{med.}$) – is consumption determined with respect to any parts of the flight from the airport starting, take off to catch up in the airport landing. The median hourly fuel consumption is the default for calculating operating costs for fuel and lubricating materials, for determining the required amount of fuel on board and for legal and commercial load range [6].

Mileage consumption (g) – is consumption attributable to one flight kilometre, flown by a light aircraft in relation to the ground. It is calculated by dividing the fuel consumed in flight over a distance, or by dividing the median hourly consumption with the median technical speed flight [6].

Mileage-ton consumption ($Q_{med.,t}$) – is determined for one ton on average for each type of aircraft and for all airliners by dividing the total consumed, or necessary fuel (in the air and on land) at a specified time (flight hour, line) for a given type of aircraft for a year for all types of aircraft and helicopters of actual or projected air traffic volume in tone-kilometre [6].

The price of fuel consumed per hour of flight is determined by the median hourly fuel consumption ($Q_{med.,h}$) and its price (C_{fuel}). The cost of the lubricant is minimal for aircraft with turbo engines and in calculations they are taken as a percentage of fuel prices. Total cost of fuel and lubricants are composed of fuel costs by line flights, unproductive flights (training, first aid, etc.), engine operation on earth [6].

It is calculated by this formula:

$$N_{pal} = \delta \times Q_{str} \times C_{pal} \ (€/hod) \quad (2)$$

δ - coefficient involving unproductive flights, engines running on earth and the proportion of lubricants.

On average in calculating the cost of fuel and lubricants for comparison of direct operating costs, the following can be taken for airplanes PM δ = 1,08 and with TVM δ = 1,12. [6]

3.4 Airport charges

Airport flight hour costs N_1 are calculated:

$$N_l = N_{spec} x\ G_{max} \quad (3)$$

Where:

$N_{spec.}$ – unit cost (specific cost) of airport costs per hour per ton of take-off weight

$G_{max.}$ – take-off weight of aircraft

3.5 Indirect costs

They include at least five basic groups:

1. Management of airplane operator.
2. Cost of flat salaries of flying and operating personnel.
3. Cost of depreciation and maintenance of the airframe equipment.
4. Cost of depreciation and maintenance of the engine.
5. Cost of disposal of the airplane.

The indirect costs can be added by the purchase price of the airplane including the cost of the aircraft type selection process and its entrance in the register.

Management and flat expenses can be broken down into further subgroups. The operator must pay the staff performing maintenance and testing airplane even when not in use. This maintenance is determined by operating rules and is conducted according to calendar time.

Depreciation costs should ensure that in the event that the aircraft system has not been modernized, the aircraft would not have any value in the end of its life-cycle.

Disposal costs are based on environmental and administrative disposal of the airplane from the operations and from the aircraft register.

3.6 Depreciation

While processing this work, it was not possible to gain real or approximate values for the depreciation of the airframe and engines. Given the frequent upgrading of this airplane type associated with prolongation of its technical life, it was not possible to make even an estimation of depreciation. Furthermore, this section provides theoretical foundations and in experimental calculations the depreciation has zero value.

Depreciation and their value depend on the purchase price of the aircraft and its technical life. The purchase price depends on the aircraft size, number of units produced in series and the costs of developing and testing a prototype. A very important value for determining depreciation is an estimate of life time. This is determined with regard to both hours of flight and moral deterioration. Flight hours are representing physical deterioration. Physical deterioration means that the aircraft as a whole and its parts cease to conform to the technical parameters and their value is shrinking [6].

Physical wear of the aircraft occurs mainly while using the aircraft in operation. It also occurs when the aircraft is out of service, since it is affected by the environment and weather conditions. Physical deterioration is reflected by decreasing operating performance and mater increasing in operating costs.

Moral deterioration can be defined as a technical obsolescence of aircraft, although it did not lose its production capacity, but with regard to technical operating parameters is outdated compared to newer and more modern aircraft. In operation, the moral deterioration manifests itself in reduced use of older aircraft in relation to new aircraft. It reduces time and fitness of the aircraft in his physical life, which is called the economic life [6].

The economic life of an aircraft means a period which is shorter than the physical fitness, but that economically justifies a new aircraft to replace the old, which is more modern and will bring more profit than loss resulting premature scrapping of the old aircraft.

To determine the depreciation amount, the following standards are used:

a) time
b) power
c) alternative
d) cumulative

- Time depreciation standard determines the amount of depreciation in € over a period of time. This standard can be expressed in % depreciation base with respect to time fitness of the aircraft. It is calculated from the formula:

$$N_{č} = \frac{C_l + C_v + C_z}{T} \ (€) \quad (4)$$

Where:
$N_{č}$ – time depreciation standard
C_l – aircraft purchase price
C_v – the aircraft disposal cost
C_z – residual value
T – planned lifetime

- Power performance depreciation standard indicated the depreciation rate in €, which is attributable to the unit of performance measurement. The rate is calculated with respect to fitness standard, which is given in the same units. Such units might be represented by flown hours or kilometres flown.

It is calculated by the following formula:

$$N_v = \frac{C_l + C_v - C_z}{I} \quad (5)$$

or

$$N_v = \frac{C_l + C_v - C_z}{L} \quad (6)$$

Where:
I – lifetime in hours flown
L – kilometres flown during aircraft life

- Alternative depreciation standard is a combination of time and power standards.
- Cumulative depreciation standard is a compromise between time and power depreciation standard. Lies in the fact that from the depreciation base that is connected with natural wear and aging, including the moral deterioration and the rest of the base from the power depreciation standard [6].

In economy, depreciation has a double mission. The first is to measure the amount of wear of the basic means and to transfer this to their own costs and the second is to create funds for the restoration of basic equipment.

3.7 The cost of staff wages

When considering staff composed of 5 air specialists with the hourly wage of 10 € it is possible to determine the average annual cost 1.35 times of the sum of gross wages. When considering 160 working hours per month, that is.

$$N_{MPR} = 12\ mes. x\ 5\ prac. x\ 160\ hod\ x\ 10\ € \quad (7)$$

$$N_{MPR} = 96\ 000\ € \quad (8)$$

Where N_{MPR} is yearly cost for the personnel salaries.

3.8 Economic analysis of costs associated with aircraft maintenance

Maintenance as prescribed by L6 means „Execution of the tasks required to ensure the continuing airworthiness of aircraft, comprising either individually or in mutual combination of overhaul, inspection, replacement, removal of defects and the incorporation of modifications of repairs " [7].

3.8.1 The cost of airframe and engine maintenance

The cost of maintenance of the airframe, engines and equipment include expenditures for the technical operation and maintenance. The maintenance costs for the purpose of comparing the direct operating costs include: salaries of the technical personnel, materials (spare parts, units, fuel...) used for testing aircraft after repairs, overhead costs and administration costs [6].

With the increasing weight of the aircraft come increasing maintenance costs to be paid per hour of flight. The costs per unit mass of the structure are however decreasing, that means the unit cost of airframe maintenance is decreasing.

With expanding thrust (power) of the engine, the cost of maintenance is increasing but also the engine maintenance unit costs are decreasing.

The level of expenditure on maintenance depends on how you can handle the specific type of aircraft and engine in production and operation [6].

The manufacturer does not indicate the costs alone for the airframe and engines. They are included in total costs of maintenance on flight hour.

Table 2. Maintenance costs

Cost category	Time data	Cost
Maintenance	1 FH	91,51 €

3.8.2 Economic analysis of costs associated with aircraft repair

According to the regulation L6, repair can be defined as follows: „Restoring aircraft product to the airworthiness status after damage or wear to ensure that the aircraft will continue to meet the designed aspects of airworthiness, which were used in the type-approval for this aircraft type [7].

3.9 Technical life of the engine and overhauls costs

Table 3. Overhauls

Cost category	Time data	Cost
Engine overhaul	TBO 3 000 FH	266 890 €
Propeller overhaul	TBO 3 000 FH	5 476 €
Hot parts inspection	TBO 1 750 FH	19 063 €
Chassis inspection	5 000 landing	9 150 €
General inspection	Every 10 years	4 956 €

Different type of engines, depending on their finishing design, structural peculiarities are differing with technical life. Life is increased in stages. From 500 hours to repair in the first year of operation up to 3000 to 5000 hours in the third and fourth year (at the time of operation from 12 to 15 years). As experience from operations shows, 1-2 overhauls are required in an average lifetime. The price of one overhaul usually represents 25 - 35 % of the purchase price [6].

For L-410 airplane engine the TBO is 3000 flying hours, which means the interval time between overhauls. Engine overhaul price is 266 890 €.

For L-410 airplane the overhauls and major inspections are performed with following intervals and costs:

The airplanes are fitted with two engines and two propeller units and a set of chassis. In accordance with the usage profile of the airplane, it is to be done 2 x 6 = 12 times the engine overhaul, 12 times the propeller overhaul, 24 times hot parts inspection, one time chassis inspection and one overhaul inspection. This makes the cost of repairs:

$$N_0 = 12\ x\ 266\,890 + 12\ x\ 5\,476 + 24\ x\ 19\,063 + 9\,150 + 4\,956\ (€) \quad (19)$$

$$N_0 = 3\,740\,010\ € \quad (20)$$

The cost of unplanned repairs is not known. Therefore there will be not included in the total cost.

3.10 Economic analysis of costs for a planned life cycle of the aircraft

Table 4. Economic analysis of L-410 airplane costs

Direct costs			
Costs	1 FH	Yearly	The whole planned life-cycle
Personnel premium costs	166 €	99 600 €	1 992 000 €
Fuel and lubricants costs	291,059 €	174 635,4 €	3 492 708 €
The cost of airframe and engine maintenance	91,51 €	54 906 €	1 098 120 €
Airport charges	11,4378 €	6 862,68 €	137 253,6 €
Indirect costs			
Costs	1 FH	Yearly	The whole planned life-cycle
Operations	unknown	–	–
Airframe depreciation	unknown	–	–
Engine depreciation	unknown	–	–
Personnel salaries	–	96 000 €	1 920 000 €

During operations of the airplane L-410 in accordance with table 6, the cost of its use will consist of the above items. As mentioned above, depreciation is not included in the results. Furthermore, it was not possible to obtain information on central time to failure and average cost to remove defects. For this reason in the repair cost items, there are only planned actions, and actions prescribed by the manufacturer.

The following table summarizes various direct and indirect costs, which affect the operation of the airplane L-410 without the purchase price of the airplane.
The sum of all cost items is :

$$LCC = (N_{PP} + N_{PHM} + N_{ÚP} + N_{LP}) + (R + N_{OD} + N_{OM} + N_{PN}) \quad (21)$$

$$LCC = 8\ 640\ 081 \quad (22)$$

Where in the first parentheses there are direct costs:
N_{PP} – premiums for the crew based on hours flown,
N_{PHM} – the cost of fuel,
N_{UP} – direct maintenance costs,
N_{LP} – direct costs of fees at foreign airports.

In the second parentheses there are indirect costs:
R – operations, which include all costs associated with ownership and airplane parking,
N_{OD} – airframe depreciation,
N_{OM} – engines depreciation,
N_{PN} – flat-rate maintenance staff salaries according to contemporary criteria.

From these calculated costs (results in the table), it is possible to further identify relevant economic indicators such as total cost per flight hour, transport costs and other.

Calculation methodology was developed in such a detail, which was allowed by the preparation process managed theory of life-cycle and by obtaining the appropriate data bases. The work can be further developed.

4 CONCLUSIONS

The accuracy of such an economic analysis of the life-cycle of regional airliner will increase, when more credible input information is obtained from aircraft and its parts manufacturer, as well as the amount of statistical data, which are related for example with wear, failure of components, system and aircraft structures. In addition to these direct costs, there are also indirect costs. The benefit is that this analysis can be applied to other aircraft type also.

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