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RESEARCH ON THE USER'S COSTS IN MOTOR VEHICLES LIFE CYCLE

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Summary
Economic trends, increasing inflation, growing costs of many systems and products, as well as budget constraints, have created awareness and aroused interest in the system/product total cost. Total cost of ownership is a key concern in consumer as well as commercial sectors. Experience has indicated that a large portion of the total costs for many systems is a direct result of the activities associated with their operation, while the scale of these costs is based on decisions made in early stages of the system's life cycle. The motor vehicle industry is still one of the largest and strongest industries in the world and its development stage nowadays is characterized by the manufacturing and exploitation of a wide range of different types and categories of motor vehicles.
This research is made on user's costs of 3 three different vehicles in a vehicle fleet in Macedonia. Various methods of maintenance such as preventive and corrective maintenance are taken into consideration. A Life Cycle Cost (LCC) model is a simplified representation of the real system. Its function is to abstract the salient features and aspects of the product and to translate them into a cost figure. A Life Cycle Cost (LCC) analysis is a process of identifying and evaluating costs associated with acquisition and ownership of a product during its life cycle. This article shows a LCC model of vehicle ownership costs. According to this model a separate LCC analysis is made for each vehicle and for 3 three different regimes of exploitation.
***Keywords**: Life Cycle Cost – LCC, LCC model, availability, ownership cost*

1. LIFE CYCLE COST (LCC)

Life cycle cost is the total cost of ownership of machinery and equipment, including its cost of acquisition, operation, maintenance, conversion, and/or decommission (SAE 1999). LCC helps change provincial perspectives for business issues with emphasis on enhancing economic competitiveness by working for the lowest long term cost of ownership which is not an easy answer to obtain [8]. As with most engineering tools, LCC provides best results when both engineering art and science are merged with good judgment to build a sound business case for action. LCC includes every cost that is appropriate and appropriateness changes with each specific case which is tailored to fit the situation.
Life Cycle Costs may help vehicle fleet's managers to envisage their costs for the next year and thus make them more successful in their budget making. Moreover, LCC awareness may also help vehicle manufacturers in making market competitive vehicles.

A primary guidance for a vehicle life cycle cost evaluation represents a standard [1]. According to such standard the vehicle life cycle costs can be divided into six periods:
1. concept and demand determination period
2. design and development period
3. manufacturing period
4. installation period
5. operating state and maintenance period
6. disposal period

The total costs incurred can be divided into two major parts, i.e. acquisition costs and ownership costs.

2. LIFE CYCLE COST (LCC) OF A VEHICLE

The LCC model, as is the case with any other model, is a simplified version of reality. It summarizes specific characteristics of the product during its life cycle and transforms them into costs. In order to be more realistic, it should [2]:

i. have all the characteristics of the product being analysed, including the environment it is used in, maintenance strategy, operation, logistics, etc.;
ii. be comprehensive and comprise all factors relevant to LCC;
iii. be simple and easily understandable and allow for timely changing of decisions and making corrections or modifications;
iv. be created in a way that will provide independent assessments of any LCC item.

In some cases a separate model may be required to make further researches of this issue, whereas in some other cases commercially accessible models may be applicable. A simple LCC model is in fact a calculation structure containing conditions and factors which may allow any cost assessment be referred to any LCC item contained therein. Each LCC model has its own flexibility and application. It is important to know the contents and conditions in which LCC models are applied in order to ensure the suitability of their application.
Before selecting a model, the scope of information needed should be compared with the results that are expected from such model application. A person acquainted with the respective model details should control it and establish all the applicable cost factors, empiric connections and other model constants and variables. Therefore, before applying any existing LCC model, it should be compared with the life cycle costs being assessed. To achieve that, costs factors and other parameters of a known example, along with an operating scenario, should be used to assess the scope within which such model may provide actual results.

Analytical studies and estimates of total costs are methods for finding life cycle costs. The objective of LCC analysis is to choose the most cost-effective approach from a series of alternatives so the least long-term cost of ownership is achieved [3]. LCC analysis helps engineers justify equipment and process selection based on total costs rather than initial purchase price. The sum of operation, maintenance, and disposal costs far exceed procurement costs. Life cycle costs are total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposal of the product over its anticipated useful life span.

In this article a LCC model of a vehicle considering the ownership costs is presented (Figure 1). The ownership cost analysis considers the following 3 three cases of various exploitation intensity expressed in mileage travelled per year:
I- 10000 km per year (actual situation in this vehicle fleet)
II – 20000 km per year (recommended for this purpose)
III – 30000 km per year (intensive exploitation)

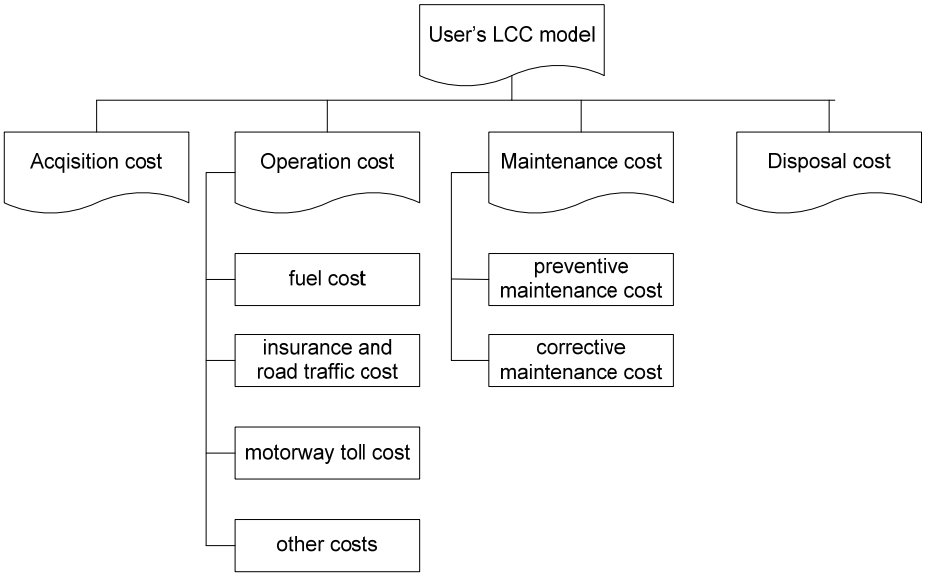

Fig 1: LCC model of a vehicle

As it can be seen from Figure 1, user costs consist of the following four elements:
1. Acquisition cost, i.e. vehicle purchase cost;
2. Operation cost;
3. Maintenance cost;
4. Disposal cost.

As previously mentioned in this research 3 three different vehicles from the Army's Vehicle Fleet in Macedonia have been taken, and they are:

- IVECO EURO CARGO 4x4
- IVECO EURO TRAKKER 4x4
- HMMWV M998
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In this paper, determination of the costs in the process of maintenance was conducted in three variants of the cost of labor as follows:

- Variant A – 1 working hour = 3€, when the maintenance is done using resources from the Republic of Macedonia Army
- Variant B – 1 working hour = 20€, when the maintenance is done by an external organization, i.e. outsourcing maintenance
- Variant C – 1 working hour = 50€, when maintenance is done during a military mission abroad

2.1 Acquisition cost

Acquisition cost, seeing from the manufacturer's point of view, can be expressed by the following equation [4]:

$$C_{PC} = C_{CD} + C_{DD} + C_M + C_S + C_{RG} \quad (1)$$

C_{CD} – costs on concept and demand determination period
C_{DD} – costs on vehicle proposal and development period
C_M – manufacture costs
C_S – vehicle sale period costs
C_{RG} – warranty period repair costs

From the user's point of view, the acquisition cost is manifested through the purchase price of the vehicle.

2.2 Operation cost

Operation cost can be expressed by the following equation [4]:

$$C_{TRV} = C_G + C_{FOL} + C_{PA} + C_{OT} + C_{PT} + C_{VG} \quad (2)$$

C_G– fuel costs
C_{FOL} – working fluid costs, oil and motor lubricant costs (if there are not included in the maintenance stage)
C_{PA} – tyres and accumulator battery costs (if there are not included in the maintenance stage)
C_{OT} – vehicle insurance and road traffic tax costs
C_{PT} – motorway toll costs
C_{VG} – driver costs

The vehicle fuel cost can be expressed by the following equation:

$$C_G = ge \cdot c_G \cdot S \quad (€) \quad (3)$$

ge (l/km) – fuel consumption for appropriate vehicle
c_G (€/l) - fuel single price
S (km) – vehicle mileage
It should be noted that fuel consumption is basically a variable size and that it depends on vehicle technical condition. For a real display of such a cost, measuring should be made of the real fuel consumption in real exploitation conditions. Tyres and accumulator battery costs in this case are taken within corrective maintenance. Working fluid costs and oil and motor lubricant costs are not considered out of the maintenance process. Being Army vehicles, they, according to the regulations, are not burdened with insurance and tax duties and are free from motorway toll costs, so, these costs, along with drivers costs, are also not taken into account in the total cost.

2.3 Maintenance cost

2.3.1 Costs on vehicle preventive maintenance

In general, preventive maintenance costs are most accurately fixed according to the preventive maintenance schedule provided by vehicle manufacturers on the basis of their own market research and experience and targeted to as high competitiveness of their vehicles as possible.
The total cost amount required to be spent on preventive maintenance during the operating state apparently depends on the number of preventive maintenance operations required to be performed on the vehicle during its usage, and on the cost amount required for carrying out such preventive maintenance operations. For the preventive maintenance cost, the following equation can be used [4]:

$$C_{OMP} = t \cdot c_M \quad (4)$$

t – operating time
c_M – average costs on preventive maintenance applied to an operating time unit that these costs are dependent on the vehicle reliability level, i.e. failure rate

2.3.2 Costs on vehicle corrective maintenance

The total cost amount necessary to spend on vehicle repairs during its operating state depends apparently on the number of failures which occur in the vehicle during its usage, and on the cost amount necessary to remove each failure. If the failure rate **λ** is regarded as a measure of reliability level, it is possible to use the following equation for repairing support costs [4]:

$$C_{OMC} = \lambda \, t \, c_R \qquad (5)$$

λ – failure rate
t – operating time
c_R – average price of the vehicle, whereas it is estimated that the price is again dependent on the vehicle reliability level, i.e. on failure rate

2.3.3 Total costs on vehicle maintenance

Vehicle maintenance generally comprises the following operations:

- care
- preventive maintenance
- corrective maintenance
- overhauls (middle and large-scale)
- control /inspection
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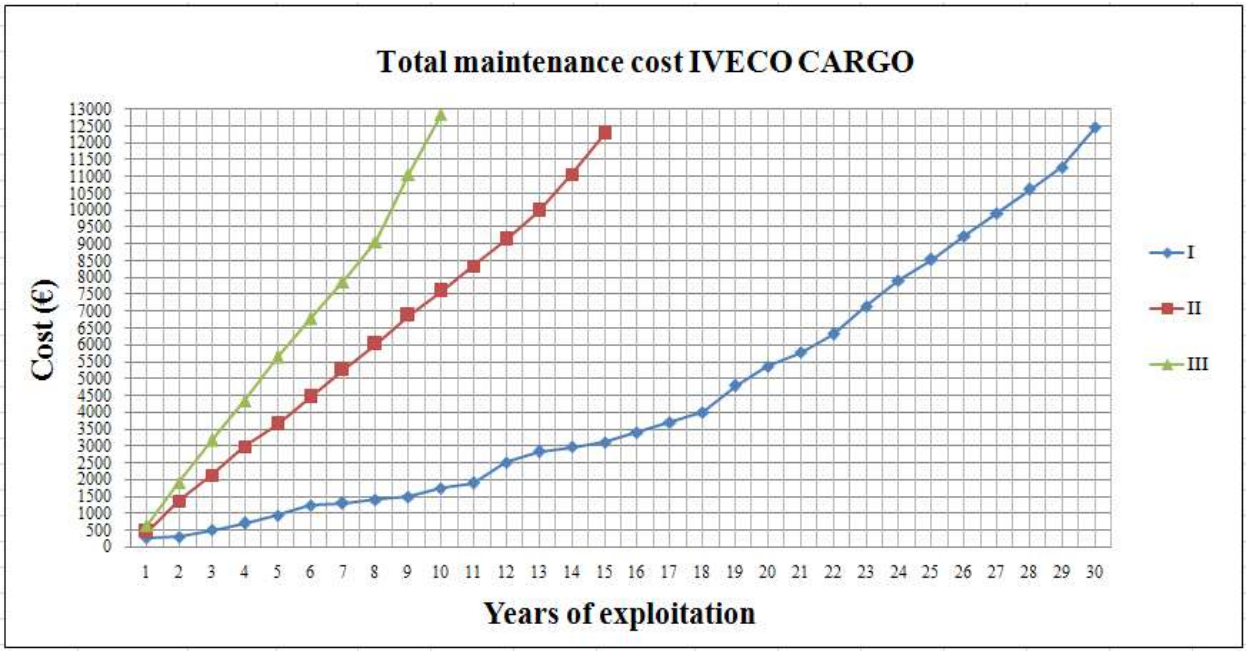
$$C_{TC} = C_C + C_{OMP} + C_{OMC} + C_O + C_{CI} \qquad (6)$$

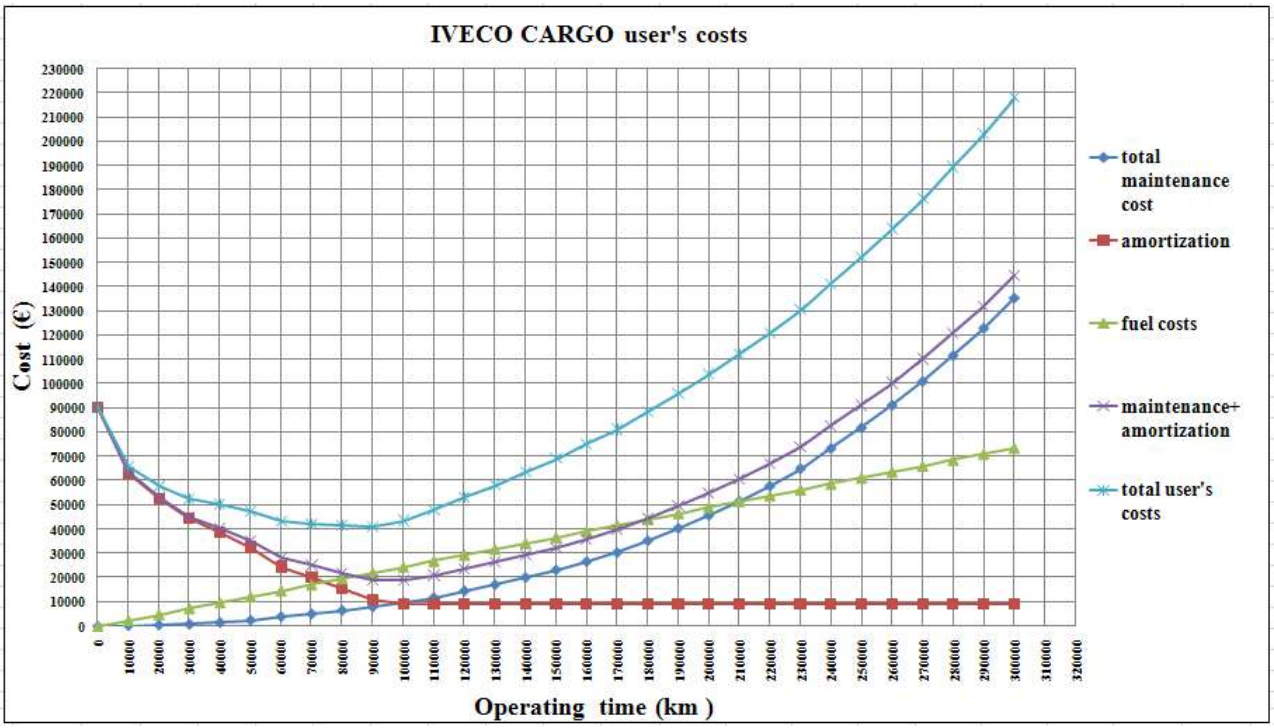


2.4 Amortization

Amortization percent is set depending on vehicle category (kilometer-category Km.K) and vehicle exploitation period (age). Vehicle category is set for every individual vehicle type of the same brand according to the SUPERSCHWAKE Catalogue [5]. Vehicle exploitation period is set from the date of first registration (as it can be seen from the traffic booklet) till the date when the vehicle was sold.

2.5 Disposal cost

Vehicle disposition can be as important as vehicle acquisition. The disposal procedure should start after a long use when both maintenance costs and vehicle amortization begin to grow rapidly. As this study reviews user costs, only for disposal cost is considered the sale price of a specific vehicle. Furthermore, the dismantling process is not taken into consideration.



3. CONCLUSION

The article describes methodology of calculating user costs on any vehicle. To carry out this task successfully, it is necessary to collect and sort data on the occurrence and relevancy of failures, costs on failures removal, preventive maintenance costs and costs on operating state. The developed LCC model on the vehicle user costs includes any influential elements found in the use of vehicles. This model is easy to understand and allows for relevant corrections and modifications. It has been verified in this research by analyses made on the relevant military vehicles of my country. Knowledge of the vehicle user costs may help vehicle maintenance engineers to envisage such costs for the next year and thus create their budget more successfully. Moreover, knowledge of such costs may also help vehicle manufacturers be more competitive.

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