Transportation of waste in the life cycle analysis

Maciej Gliniak1, Anna Lis1

1University of Agriculture in Krakow, Faculty of Production and Power Engineering, Institute of Agriculture Engineering and Informatics, Mickiewicz Av. 21, 30-120 Krakow, Poland

maciej.gliniak@urk.edu.pl

Abstract. The life cycle of the product is an assessment of the potential impact of the product on the natural environment. During the product life cycle, we take into account the stages through which the product passes throughout its entire life cycle. At every stage of the life cycle, transportation is a necessary element which is, unfortunately, significantly harmful to the environment. The paper presents costs and remuneration related to the transportation of waste and finished products. The price of diesel oil has the largest share in the structure of transportation costs. The analysis presents remuneration for the transportation of waste and finished product, taking into account all costs incurred by the carrier. The profitability of product transport is greater than the transportation of waste.

1. Introduction

Waste transportation has a large share in the structure of waste management costs. According to the definition [1], transportation is the movement of people and objects by means of transport. The transportation of waste involves the shipment of waste from the place of its production to the place of its processing, disposal (including storage) or collection places, including their transfer to and from the recipient of waste. Waste transportation is a difficult and specialized task for carriers. Transportation companies and their drivers must have special qualifications as they often carry substances that are potentially dangerous for the environment and for people. Vehicles transporting waste must be adequately equipped with special equipment and means of protection. Their technical condition cannot raise any objections and must meet all norms specified by law. Waste transportation can account for up to 70% of the total waste management costs [2].

Logistics companies providing services in Europe must bear charges for the use of transport infrastructure - roads. The European Union has introduced Eurovignette in most countries to recover environmental costs, as well as to build, maintain and repair roads. Charges are levied for the use of motorways, tunnels, bridges and mountain passes. The cost of the toll depends on the amount of exhaust emissions released and on the time of using the road infrastructure [3].

Competition in the market is very high because road transportation is the most popular method of product delivery and accounts for 44% of total transport services. From year to year, there are more and more logistics companies in Poland as well as in other countries. Therefore, road transportation pollutes the environment the most, causes climate change, emits noise and leads to road accidents.
The product life cycle is the period in which the product is on the buyers' market. All products have a specific life cycle, short which can last only a few weeks or a long lasting even several years. The life cycle of the product may illustrate the phenomenon of gradually acquiring and losing the ability to satisfy the consumer's needs. Considering the environmental life cycle of the product, reference should be made to the Environmental Life Cycle Assessment (LCA) concept. It is used to assess potential impacts on the environment and it constitutes a technique for assessing environmental aspects throughout the life of the product [4-6].

The main task of the "life cycle analysis of the product" is to examine the impact of the product on the natural environment and natural resources. The first stage in this analysis is the preparation for production, i.e. the extraction of raw materials and the supply of energy. The next stage of the analysis is the production and consumption process, ending with waste management. At each stage of the product life cycle, transportation must be considered. In terms of the environment, the life cycle is perceived through the product usability [7]. It is a process of gradually acquiring and losing the ability to satisfy specific needs.

The purpose of the article was to determine the impact of the organization of waste transportation and its cost-consumption on the product life cycle.

2. Material and methods
The subject of the analysis, which is the aim of the article, were costs incurred by an international forwarding company dealing with road transportation during delivery of waste and a finished product manufactured from it in 2019. Analyzing the road transportation regulations for a truck vehicle to complete the route from Randers - DK to Hoya - DE, taking into account driver's pause of 45 minutes, we need 7h 30 min. One-way transportation can be accomplished in one day. Table 1 includes costs and revenues. All data has been converted into 1 day, because this is the length of the delivery considering the transportation requirements that must be met by carriers in EU countries. In order to achieve the set objective, it was necessary to compare individual data related to the transportation of waste and products.

| The number of kilometers travelled | 486 km |
|-----------------------------------|--------|
| Road tolls (waste transportation)  | 0,15 euro/km |
| Road tolls (product transportation)| 0,15 euro/km |
| The cost of diesel oil             | 1,20 euro/l |
| Costs of civil liability insurance | 7,1 euro/day |
| Car accident insurance costs (damage waiver) | 7,75 euro/day |
| Costs of accidental death and dismemberment insurance | 0,1 euro/day |
| Depreciation costs                | 10,98 euro/day |
| Repair costs                      | 2,32 euro/day |
| Fuel consumption of the truck     | 30l/100km |
| Driver's rate (subsistence allowance) | 50 euro/day |
| Driver's rate (basic)             | 9,3 euro/day |
| The rate for the company for waste transportation | 0,96 euro/km |
| The rate for the company for transporting the product | 0,92 euro/km |
On the basis of information received from the Enterprise, the costs of transportation, remuneration and total profit were calculated. Graphs were drawn, which were presented in the analysis to determine the factors affecting the financial result. Due to the issue of waste and product transportation, the company has made available the formulas that they use to calculate the total profit for a specific transport. The revenue for the company was described by the equation. (1).

\[ P = (CU) - (KT) \]  

(1)

where: \( P \) - revenue (profit), \( CU \) - service price, \( KT \) - transportation cost

The price of the service is described by equation (2).

\[ CU = (S) \times (L) \]  

(2)

where: \( CU \) - service price, \( S \) - company rate per km, \( L \) - route length

The basic components of transportation costs are described by equation (3).

\[ KT = (KP) + (KD) + (KK) + (KU) + (KA) + (KN) \]  

(3)

where: \( KT \) - transportation cost, \( KP \) - fuel cost, \( KD \) - road tolls, \( KK \) - driver's cost, \( KU \) - insurance costs, \( KA \) - depreciation cost, \( KN \) - repair costs

3. Results and discussions

Data contained in Table 2 show the costs that the company had to incur during the transportation of waste and product. All values have been converted into one transport performed.

| Specification | Waste transportation | Product transportation |
|---------------|----------------------|------------------------|
| KP            | 190                  | 190                    |
| KD            | 72.9                 | 72.9                   |
| KK            | 59.3                 | 59.3                   |
| KA            | 10.98                | 10.98                  |
| KU            | 14.95                | 14.95                  |
| KN            | 2.32                 | 2.32                   |
| Total:        | 350.45               | 350.45                 |

The costs of road transport are invariable, taking into account the transportation of waste and the transportation of finished products. All charges that are incurred during the transport of delivered goods are the same if the service is provided with the same mode of transportation. They depend on the current price of diesel oil. In Table 1, the price of diesel oil for which the transportation company had to pay in 2016 was averaged. Fuel costs are the dominant value in transportation costs - 54.2% of all costs. Road tolls depend on the means of transport and exhaust emissions. In Denmark and Germany, it is 0.15 euro / km with a car that meets Euro 5 standards. The smallest share in the transportation costs are the costs of repairs, which constitute about 1%. Repair costs were calculated for one day and per one truck set, adding up the costs of operating parts and the prices of technical services during repairs performed within a year. The insurance costs presented in Table 2 depend mainly on the insurance company. The data contained in Table 3 demonstrate the remuneration for the company for the performed transportation service. The price of the service is an individual value, which is set between the client and the carrier. Before the order is processed, the company performs a balance sheet that shows the profitability of possible transport. The rate per kilometer travelled often
depends on the freight carried and the country in which the service is performed. In the case of a company, the rate for waste transportation is 0.87 EUR / km and 0.92 EUR / km for product transportation. The price of transportation of the finished product is higher.

**Table 3. Revenue from transportation (EUR)**

| Specification | Waste transportation | Product transportation |
|---------------|----------------------|------------------------|
| CU            | 422,82               | 447,12                 |
| KT            | 350,45               | 350,45                 |
| P             | 72,37                | 96,67                  |

The final remuneration for the company is presented in Table 3, taking into account the costs that the enterprise had to incur and the remuneration received for the service provided. It is more cost-effective for the enterprise to transport the finished product, where the price of the service is higher, and the transport costs are the same as for the transportation of waste. The company provides a combined transport service for both goods because it is a closed circuit. The route includes a one-way transfer of waste to a recycling company where waste is discharged. After finishing the obligatory pause and all activities related to the regulations, the vehicle approaches the place of loading. The finished product which is paper is transported the other way to Denmark.

4. **Conclusions**

By receiving relevant data from the company, it was possible to calculate the costs of road transportation of waste and processed finished products. Taking into account the components of the transportation costs, the largest share in them is the current price of fuel [8-11], which the company has no influence on. The costs do not depend on the transported cargo, the cost of waste and finished products transportation is the same. Road tolls depend on the number of axles in the transporting unit and on the fuel emissions. In the company, all trucks meet the Euro 5 and Euro 6 standards in order to reduce road tolls. This is due to the fact that road transport has a significant impact on air pollution, which poses threats to the environment as well as the human health [12]. Road transportation is the most popular method of carriage and accounts for 44% of goods transportation.

The analysis of the company shows that the company generated revenue of 72.37 euros for waste transportation and 96.67 euros for product transportation. Waste transportation has a smaller financial impact on the product life cycle than the product transportation, and the analysis has demonstrated that in the product life cycle, the transport in each link should be calculated separately. Waste transportation is profitable for companies with a larger fleet of vehicles.

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