

# The assessment of the truck operation efficiency in safety engineering aspect

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**Abstract.** The article covers the aspect related to the assessment of the efficiency of truck operation in safety engineering aspect for the management of supply chain security. The publication contains an analysis of the functioning of a selected transport company. The concept of operational efficiency of truck was defined with taking into account the standards of the European Union. The essence of securing the delivery process in a selected example of road transport was also presented too. Then, an assessment and forecast of the efficiency of the truck operation was made with the possibility of safe delivery of goods. In order to solve the problem, a research hypothesis was determined and selected theoretical and empirical methods were used to determine the correlation between the efficiency of truck operation and securing the supply chain, supported by the science of safety engineering.

## 1 Introduction

The issue of assessing the efficiency of truck operation is an extremely complex problem and a very important for the security of the supply chain management of goods and services by the transport company. The rationale research was undertaking the earlier through scientific observation of the correlation between the efficiency of truck operation and securing the supply chain, which is supported by safety engineering. Therefore, the main research problem is to determine the appropriate level of quality of the delivery goods securing in the European Union. It was relating into account the efficiency of truck operation. Taking of consideration the solution of the main research problem, the following should be determined by:

- the level of efficiency of truck operation,
- the effectiveness of the delivery by the transport company,
- basic elements ensuring safe delivery of goods,
- a measure of the efficiency of vehicle operation in terms of deliveries.

In order to assess the efficiency of the truck operation with regard to securing the implementation of supplies, the following should be specified by:

- a set of coefficients on the basis of which it will be possible to compare the efficiency of operation of individual trucks carrying out transport orders in the tested period of time,
- significant technical and operational features characterizing the delivery process,

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- a set of variables describing the delivery process along with information on the truck operation.

In view of the above, an index analysis of the efficiency of truck operation was carried out in relation to securing deliveries in the European Union in 2018-2020.

## 2 The efficiency of truck operation

Making business decisions in transport processes is associated with the analysis of technical parameters of vehicles and the assessment of the effectiveness of actions taken. In terms of securing deliveries, the most important aspect influencing the reliability of the transport process, which is the effective use of trucks. In practice, it is confirmed that only when the ordered transport is performed. In accordance with the guidelines contained in the transport order, the customer ordering the service is obliged to pay for it. Trucks are the purpose to transport loads related to special technical requirements based on defined operational indicators. In accordance with PN-N 04001: 1982 and PN - 93 / N -50191 [1, 2] the operation is defined as a set of purposeful organizational, technical, social and economic activities of people with a technical object and the mutual relations between them from the moment of taking the object to use in accordance with its intended use, until its liquidation. The occurrence of emergency situations during the implementation of deliveries forces vehicle users to rationally manage them and to take actions that, in a specific situation can be secure the smoothness of the transport process.

B. Lockwood defines efficiency as an activity devoid of waste and focused on achieving the best result within the scope of available resources and technologies [3]. In general terms, it is defined as the ability to use the available resources in such a way as to achieve a given goal in the most effective and least wasteful way. The essence of measuring efficiency understood in this way is to compare the achieved effect with the inputs used [3]. According to the theory of organization, efficiency is treated as the broadest in terms of meaning among such concepts as: efficiency, productivity, economy, rationality and effectiveness [4,5]. In publications [6,7], the authors confirm that the efficiency of transport companies is a universal concept, determined by rational vehicle management. The transport tasks performed in management supply chain companies. For companies carrying out transport orders is as the measurable feature of the efficiency of truck operation, which is always the revenue from the implementation of transport orders and the costs resulting from this implementation. Optimum management of truck operation should always be geared towards maximizing revenue and minimizing costs  $K_{min}$  [8]:

$$Realization\ of\ deliveries \rightarrow E_f(\bar{x}) = \begin{cases} P_{max} \\ K_{min} \end{cases} \quad (1)$$

The efficiency of truck operation in the economic aspect is determined by means of measures [9]:

- unit revenue  $d_i$  [PLN / h] resulting from the operation of the vehicle per unit of time;
- total revenue  $D_i$  [PLN] obtained from the operation of the vehicle in the period of time  $(0, t)$ :

$$D_i = \sum_{i=1}^n t_{ij} \cdot d_i; \quad (2)$$

- unit costs jednostkowe koszty  $c_i$  [PLN / h] of vehicle operation and maintenance;
- total costs  $C_i$  [PLN] of vehicle operation and maintenance over a period of time  $(0, t)$ :

$$C_i = \sum_{i=1}^n t_{ij} \cdot c_i. \quad (3)$$

Security of the effective implementation of deliveries in the transport process is a measurable process and requires an assessment of the efficiency of truck operation.

### 3 The security of the delivery process in a selected example of road transport

The main goal of a transport company is to carry out deliveries efficiently for customer. The complex and dynamic process of truck operation requires constant monitoring of the technical parameters of vehicles, which are exceeding as the permissible limits.

It may be cause failure of individual vehicle in his functional systems. It should be noted that failures which result in not only additional costs reducing the company's income, but also downtime and the inability to make deliveries.

Four trucks were selected for the analysis of the research on the process of carrying out by the transport company. They were assessed for effectiveness in a 2-year period. Each analysis and synthesis concerned the execution of a delivery order from a contractor by a truck, which included the following information:

- order execution date,
- place of loading and unloading,
- time windows during which the cargo is to be picked up and delivered,
- type of cargo and conditions of its carriage,
- mass of transported cargo,
- unit price for the service.

The securing of deliveries are consisted in organizing by the transport company, which is guarantee the effective implementation of the assumptions specified in the transport order. Each transport order has been defined as 1 of 6 loading places and 1 of 57 delivery places in one of the distribution centers, which is located in the European Union.

The identification of loading and unloading in the delivery process is presented in table 1.

**Table 1.** The identification of loading and unloading in the delivery process.

Loading place	Unloading place	
	Distribution centers	Number of delivery places
1	A	7
2	B	11
3	C	14
4	D	6
5	E	7
6	F	12

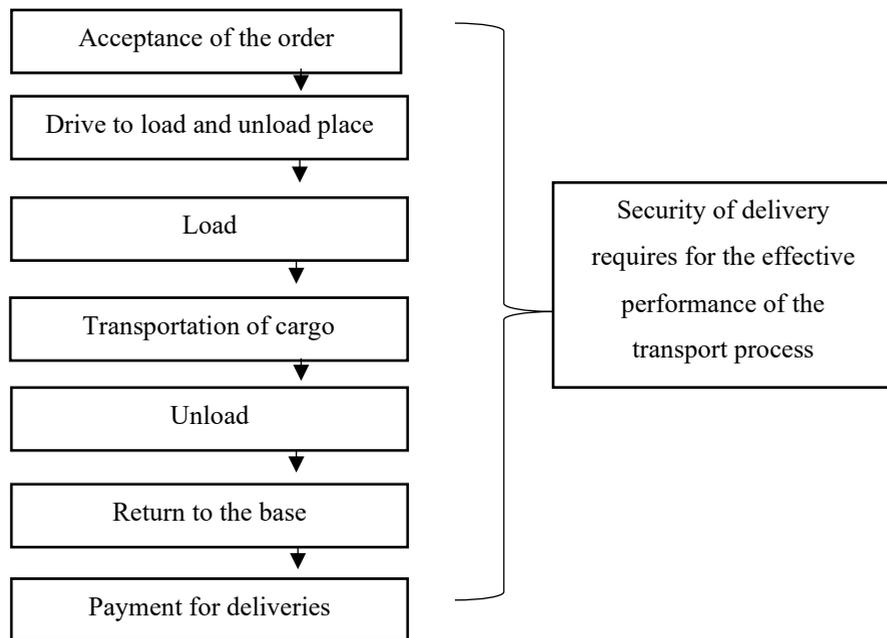
The process of truck operation is determined by the transport process being carried out and covers the scope of activities, where the vehicle is involved from the moment it leaves the base to the place where the load or unload, after that until it returns to the base. The course of deliveries is carried out in accordance with the diagram fig. 1.

The implementation of deliveries within the scope of the accepted transport order includes:

- access to the place of loading,
- loading and transportation of cargo along a specified route,
- unloading at the place specified by the client.

The effect of the successful delivery by the transport company is issuing an invoice and obtaining income from the service.

Rational management of the operation process is a key element ensuring safe and reliable delivery.



**Fig. 1.** The course of deliveries. Source: own science.

#### 4 The assessment of the efficiency of truck operation in the delivery proces

In order to assess the efficiency of truck operation in terms of deliveries, it is necessary to develop a set of coefficients on the basis of possible to compare the efficiency of operation of individual trucks carrying out transport orders in the analysed period. The basis for the assessment of the vehicle operation process is the determination of the essential technical and operational features characterizing the delivery process. The technical characteristics of the analysed trucks are presented table 2.

**Table 2.** The technical characteristics of the analysed trucks.

Number of truck	Type of truck	Year of production	Weight [kg]	Max package [kg]	Engine capacity [dm <sup>3</sup> ]	Initial mileage for the day 1.01.2016 [km]	Market value of the vehicle for 1.01. 2016 [PLN]	Factory fuel consumption on a combined cycle [dm <sup>3</sup> /100km]
1	Renault Master	2011	2 400	1 100	2,3	59 255	29 400	12
2	Renault Master	2011	2 400	1 100	2,3	203 362	26 400	12
3	Fiat	2011	2 270	1 230	3,0	396 725	30 600	13

	Ducato							
4	Citroen Jumper	2010	2 300	1 200	2,2	113 610	30 000	12

The development of a set of variables describing the delivery process also included the collection of information on the operation of trucks. The set of variables characterizing technical features has been supplemented with the features of the operation process and includes:

- $M_p$  – type of truck [RM, RS, FD, CJ];
- $R_p$  – year of production [year];
- $d_i$  – unit income [PLN/h];
- $D_i$  – total income [PLN];
- $c_i$  – unit cost [PLN/h];
- $C_i$  – total cost [PLN];
- $P_r$  – initial mileage of truck [km];
- $P_u$  – total mileage of truck [km];
- $P_k$  – final mileage of truck [km];
- $L_z$  – number of orders [no];
- $L_{zt}$  – the average duration of the order [h];
- $W_s$  – the average value of the overload coefficient [%];
- $M_u$  – total weight of load transported [t];
- $C_u$  – total track operating time [h];
- $J_u$  – total driving time of track [h];
- $T_u$  – total stationary time of truck [h];
- $C_{NZ}$  – total inability time of truck [h];

On the basis of the developed set of variables, it is possible to evaluate the effectiveness of the operation process of trucks that deliver to distribution centers. Proper management of the trucks operation is aimed at increasing their technical efficiency, necessary for the effective implementation of deliveries. The evaluation of the efficiency of the operation process and its impact on the security of supply execution is possible on the basis of defined operational coefficients:

#### Coefficient of utilization working time of truck $E_1$ :

$$E_1 = \frac{C_u}{E_w} \cdot 100, \quad (5)$$

where:

$C_u$  – total operating time of truck [h];

$E_w$  – the maximum, total operating time of truck [h].

For the analysed period, it was assumed that the maximum total operation time of truck is 5463 h and assuming that the trucks do not perform transports on Sundays and public holidays, and their maximum daily working time is 9 hours.

**Coefficient of effective work of truck  $E_2$ :**

$$E_2 = \frac{J_u}{C_u} \cdot 100, \tag{6}$$

where:

$J_u$  – total driving time of truck [h].

**Coefficient of intensity operation of truck  $E_3, E_4$ :**

$$E_3 = \frac{P_u}{J_u}, \tag{7}$$

where:

$P_u$  – total mileage of the truck [km].

$$E_4 = \frac{M_u}{P_u}, \tag{8}$$

where:

$M_u$  – total weight of the load transported [t].

**Coefficient of truck technical availability  $E_5$ :**

$$E_5 = \frac{C_u}{C_u + C_{NZ}}, \tag{9}$$

where:

$C_{NZ}$  – total inability work time of truck [h].

For trucks under repair after the breakdown, the total inability work time of truck was determined in accordance with the formula  $C_{NZ} = L_{d1} \cdot L_{zt}$ , where:  $L_{d1}$  - the number of days the truck is repair and  $L_{zt}$  - the average duration of the transport order.

**Coefficient of utilization of the utility potential of truck  $E_6$ :**

$$E_6 = \frac{P_k}{R_d}, \tag{10}$$

where:

$P_k$  – final mileage of the vehicle [km];

$R_d$  – total service life [km].

According to the information contained in the Catalog of Standards for the Operation of Civil Engineering, the target operating standard for delivery vehicles is 15 years or 450,000 km [10].

**Economic efficiency coefficient of truck  $E_7$ :**

$$E_7 = \frac{D_i}{M_u \cdot P_u}, \tag{11}$$

where:

$D_i$  – total income [PLN].

The data set presenting the values of the variables as a whole is the basis for the analysis and comparison of the efficiency of the operation process for each truck. On the basis of the developed data set and the defined service coefficients present table 3. The results are describing the effectiveness of the truck operation process, as shown table 4.

**Table 3.** A set of technical and operational variables for assessing the efficiency of truck operation.

Number of truck [no]	1	2	3	4
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$M_p$	Renault Master	Renault Master	Fiat Ducato	Citroen Jumper
$R_p$ [year]	2011	2011	2011	2010
$D_i$ [PLN]	473 562	457 412	473 021	377 413
$C_i$ [PLN]	284 519	295 827	303 362	273 802
$P_r$ [km]	59 255	203 362	396 725	113 610
$P_u$ [km]	204 498	205 555	216 755	205 950
$P_k$ [km]	263 753	408 917	613 480	319 560
$L_z$ [no]	598	590	579	563
$L_{zt}$ [h]	7,84	7,78	8,59	8,87
$W_s$ [%]	133	150	136	115
$M_u$ [t]	871	975	966	779
$C_u$ [h]	4688,95	4591,72	4973,03	4993,27
$J_u$ [h]	4165,10	4120,60	4335,73	4117,60
$T_u$ [h]	523,85	471,12	637,30	875,67
$C_{NZ}$ [h]	94,09	85,61	154,60	58,51

**Table 4.** Summary of the operational efficiency coefficients of trucks.

Number of truck[no]	1	2	3	4
<b>Coefficient of utilization working time of truck [%]</b>	89	84	91	91
<b>Coefficient of effective work of truck [%]</b>	89	90	87	82
<b>Coefficient of intensity operation of truck (total mileage) [km/h]</b>	49,10	49,88	49,99	50,02
<b>Coefficient of intensity operation of truck (total weight) [t/km]</b>	0,0043	0,0047	0,0045	0,0038
<b>Coefficient of truck technical availability</b>	0,98	0,98	0,97	0,99
<b>Coefficient of utilization of the utility potential of truck [%]</b>	59	91	136	71
<b>Economic efficiency coefficient of truck [PLN/tkm]</b>	0,0026	0,0022	0,0022	0,0023

Based on the ratio analysis, the efficiency of truck operation was assessed in terms of securing deliveries. The truck 1 with the lowest initial mileage obtained the highest value of the unit revenue  $d_i = 101$  PLN/h and at the same time, the highest value of the economic efficiency ratio  $E_7 = 0.0026$  PLN/tkm. The largest number of orders  $L_z = 598$ , but completed the lowest mileage  $P_u = 204,498$  km. The trucks also adopts the lowest value of the intensity factor  $E_3$  and the second lowest value of the intensity factor  $E_4$ .

As a result, the truck's technical readiness to undertake the delivery is  $E_5 = 0.98$ .

The truck 2 obtained the lowest value of the vehicle working time utilization coefficient  $E_1 = 86\%$ , however, it adopted the second highest value of the unit income  $d_i = 100$  PLN/h and the highest value of the unit cost  $c_i = 64$  PLN/h. The truck accepted 590 orders and achieved the highest value of the overload coefficient  $W_s = 150\%$ .

It is also characterized by the highest value of the effective work coefficient  $E_2 = 90\%$  and the highest exploitation intensity coefficient  $E_4 = 0.0047$  t/km.

The truck technical availability coefficient  $E_5 = 0.98$ . The truck takes the lowest value of the economic efficiency coefficient  $E_7 = 0.0022$ .

For truck 3, the working time utilization factor takes one of the two highest values,  $E_1 = 91\%$ . The truck has the highest value of the mileage in the studied period, it is also the truck with the highest value of the initial mileage. As a result, the value of the truck wear technical range has the highest value  $E_6 = 136\%$ .

The truck 4 is characterized by the highest mean value of the order execution time  $L_{zt} = 8.87$ h and the total vehicle operation time  $C_u = 4993.27$  h.

The total time of truck inability is the lowest, which is confirmed by the technical availability ratio at the highest level, i.e.  $E_6 = 0.99$ .

## 5 Conclusions

The aim of the publication was to assess the efficiency of truck operation in safety engineering aspect, where the conclusions were determined by the scientific problem in following terms:

- the use of appropriate delivery models allows you to maintain an appropriate level of quality of transport orders,
- optimization of the picking process in supply chain management increases profits and customer satisfaction,
- properly defining the concept of operational efficiency of truck with taking into account the European Union standards, which improves their functioning.

Summing up, the publication presents the essence of securing the delivery process on the selected example of road transport, where it includes an analysis of the functioning of the transport company. In addition, the concept of operational efficiency of truck was defined for reducing costs, increasing more profits and giving customer satisfaction.

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