ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XV [2017] – Fascicule 1 [February]

ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

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TRANSPORTATION METRICS FOR EVALUATION OF TRANSPORT ACTIVITY

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Abstract: The measurement of processes and activities by KPIs (key performance indicators) provides a basis for understanding performance capabilities and improvement opportunities. KPIs are frequently used in general business to evaluate the success of the entire enterprise and play a key role in helping an organization define and measure its progress towards the defined goals. This paper emphasizes the aims of performance measurement of transport activities. Structure of logistics indicators will be defined which can be used for evaluation of the transport activity of a forwarding company. Evaluation of logistics indicators relating to transport activity can provide useful information because the analysis of historic data provides a real view of the company activity.
Keywords: key performance indicator, time utilization, transport way utilization, fuel usage

INTRODUCTION

Harrington states that "If you cannot measure it, you cannot control it. If you cannot control it, you cannot manage it. If you cannot manage it, you cannot improve it" [1]. It is absolutely true for business processes. Improving logistics efficiency and effectiveness requires transparency of the current processes.

Logistics performance management is the key to quantifying the actual state of a process and improvement possibilities. Performance measurement and metrics have important role to define objectives, evaluate performance and determine future actions.

A key performance indicator (KPI) is a type of performance measurement. Key performance indicators are frequently used in every part of our life and in general business to evaluate the efficiency of activities [2,3]. Transportation Metrics are the tools for evaluating the transportation processes. These metrics are used by companies to measure their own values with against competition and the industries current trend. KPIs vary for different types of transportation modes.

Common Key Performance Indicators used for Transportation Metrics are the followings [4]:

- optimize load fulfilment,
- vehicle time utilization,
- net tone kilometre,
- quantity per shipment.
- empty ways (carried no freight),
- average freight revenue per ton-kilometre,
- fuel usage / ton / km,
- freight cost per unit shipped,
- transit time, etc.

The goal of this study is the performance measurement of road transport activity. At first the structure of transport indicators were elaborated relating to vehicles and categories of vehicles.

Based on the elaborated structure of transport indicators, a case study will be described. The elaborated method can be widely used at most of small transport or forwarding companies.

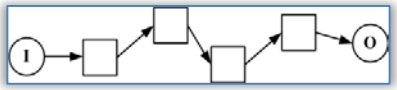
LITERATURE REVIEW AND METHODOLOGY

The author evaluated lot of literatures (most important of them are listed in the reference list) relating to general characteristics of road freight transport and performance measurement which provided the theoretical background of the recent study.

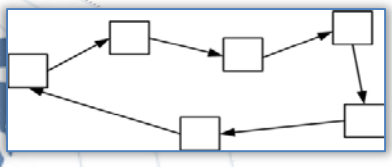
Lot of literature discuss the importance and characteristics of freight transportation [5,6]. There are lot of literature which discuss general performance measurement methods and often used KPIs [7,8] and logistics literature rarely deals with introduction of logistics performance indicators [9, 10].
Transportation Metrics are the tools for evaluating the transportation processes. KPIs vary for different types of transportation modes [11,12]. There are also a number of performance characteristics for selecting the adequate mode of transportation.
The need to apply performance measurement systems (PMS) is highlighted in the literature. A proper performance measurement system is a key for creating transparency for improvement of process performance. There are lots of performance measurement system, e.g. Balanced Score Card, Performance Prism, Performance Pyramid, ProMES, individual performance measurement methods, etc. After a detailed literature review on PMS the author focused on the need of a transport companies. The elaboration of an own PMS, required by a contracted transport company, was started with the definition of the client's requirements, definition of the objectives for the PMS's application.
After it the most important performance indicators and the structure of the indicators were defined.
A simple excel application was developed for the support of the evaluation of historic data.
Finally the evaluation of the company activity was completed based on the available historic database.

NETWORK STRUCTURES OF TRANSPORT SYSTEMS

The three basic organizational structures (Figure 1) of achievement of transport tasks (connections of stations) are: line structure, ring structure and star structure [2]. The stations can be the site of the company, station where the products to be transported are loaded in and station where the products to be transported are loaded out. Depending on the locations of the stations and the freight demand, the stations can be linked in different ways forming more complex networks. Combined networks are resulted from the connection of line, ring and star networks which are: line-star-network, star-cluster-network, ring-line-network.
The most common used structures in road freight transport are the alternatives of ring structures and star structures. The most often applied structure in international road freight transport is the ring structure so called round trip.



a) line structure


b) ring structure

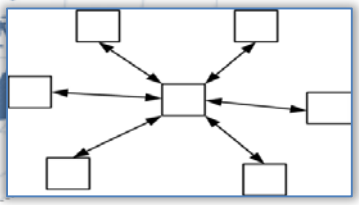

c) star structure

Figure 1. Network structures of transport systems

ELABORATION OF TRANSPORTATION PERFORMANCE INDICATORS FOR EVALUATION OF TRANSPORT ACTIVITIES

At first the structure of logistics indicators (KPIs) were elaborated which can be evaluated based on the available database in the frame of an R+D project completed for a transport company (this study shows a case study but the elaborated method can be widely used at most of small transport or forwarding companies.).
Structure of logistics indicators relating to vehicles and categories of vehicles can be seen in Figure 2. The above mentioned KPIs were the base for an excel application, which was also developed.
After it the elaborated logistics indicators relating to vehicles and categories of vehicles were evaluated based on the available historic data.
We (the author and Ákos Izsai student) completed the examination of the before mentioned logistics parameters for the transport activity of 10 vehicles of a forwarding company based on the available database (for a representative 1 month interval). Some example for the calculation and results of evaluation is shown in the next part of the paper. The examined 10 vehicles can be divided into two groups according to transport capacity: camions (5 pieces) and light trucks (5 pieces).

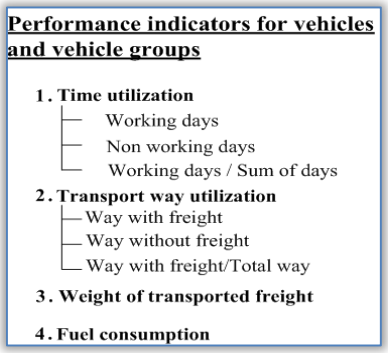


Figure 2. Structure of logistics indicators

Statistical evaluation of KPIs

It is worth to complete the evaluation of the before mentioned indicators based on the following mathematical statistical parameters, which can provide useful information relating to the characteristics of data structure:

» minimal value of the examined indicator: η_{min} ,

» maximal value of the examined indicator: η_{max},
» scattering: σ,
» expected value: $\bar{\eta}$,
» ratio of scattering and expected value: $\varphi_1=\sigma / \bar{\eta}$,
» ratio of maximal value and expected value: $\varphi_2= \eta_{max} / \bar{\eta}$,
» ratio of minimal value and expected value: $\varphi_3= \eta_{min} / \bar{\eta}$.

CALCULATION METHODS FOR DIFFERENT LOGISTICAL INDICATORS AND SAMPLES FOR THE EVALUATION OF THE MOST IMPORTANT INDICATORS

In this chapter the calculation methods for the different logistical indicators will be described and samples for the results of the evaluations completed by our developed excel application will be showed. The developed application provides the possibility of a very detailed evaluation of indicators defined in Figure 2 for a selected examination time interval. Numerical and graphical evaluation of a given indicator is also provided (see in Figure 3-13).

Time utilization of vehicles

Time utilization of vehicles in a given time interval can be calculated by the following equation:

$$\eta_{T\,i} = \frac{T_{W\,i}}{T_{W\,i} + T_{NW\,i}} \tag{1}$$

where: $\eta_{T\,i}$ – time utilization of vehicles or transport loops, i – index is relating to vehicles, which can be used for the individual vehicles, categories of vehicles (e.g. camions or light trucks), or all of vehicles, $T_{W\,i}$ – working days (time that vehicles are used for transportation) of vehicles or groups of vehicles [day], $T_{NW\,i}$ – non working days (time that vehicles are not used for transportation) of vehicles or groups of vehicles [day].

❖ **Evaluation of time utilization of vehicles**

Table 1 shows the distribution of working days and utilization of 10 vehicles in a given month. Table 2 summarizes the mathematical statistical evaluation of time utilization. Figure 3 plots the utilization of vehicles in a given month.

Table 1. Data for time utilization of vehicles

Identifier of vehicles	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Working days	17	14	20	17	17	26	26	15	16	19
Utilization of vehicles	0,567	0,467	0,667	0,567	0,567	0,867	0,867	0,5	0,533	0,633

Table 2. Statistical evaluation of time utilization of vehicles

Minimal value η_{tmin}	Maximal value η_{tmax}	Expected value $\bar{\eta}_t$	Scattering σ_{η_t}	$\varphi_1 = \sigma_{\eta_t} / \bar{\eta}_t$	$\varphi_2 = \eta_{tmax} / \bar{\eta}_t$	$\varphi_3 = \eta_{tmin} / \bar{\eta}_t$
0,567	0,867	0,623	0,140	0,226	1,392	0,91

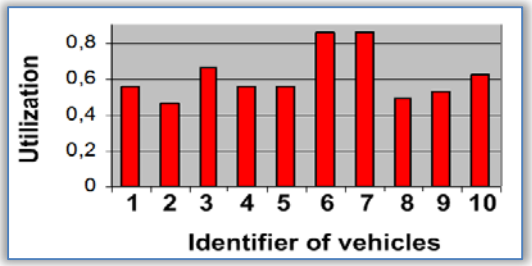


Figure 3. Time utilization of vehicles

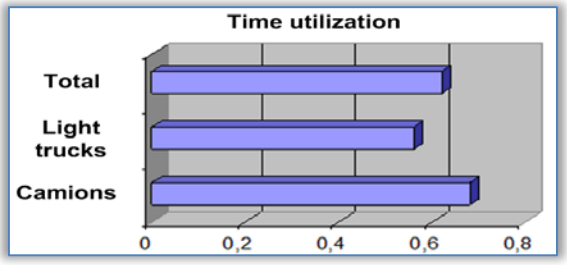


Figure 4. Time utilization of vehicle groups

❖ **Evaluation of time utilization of vehicle groups**

Analysis can be also completed for vehicle groups, which are the light trucks and camions. The results can be seen in Figure 4.

Transport way utilization of vehicles

Transport way utilization of vehicles is the ratio of the realized transport way of individual vehicles and the total transport distance of the fleet in the examined time interval. This utilization can be calculated as follows:

$$\eta_{Li} = \frac{L_i}{L_{sum}} \tag{2}$$

where: η_{Li} – transport way utilization of vehicles, i – index is relating to vehicles, or vehicle groups, L_i – length of transport way of individual vehicles [km], L_{Sum} – length of transport way of the fleet [km] in the examined time interval.

❖ **Evaluation of transport way utilization of vehicles**

Distribution of total transport distances of vehicles in the examination time interval is included in Table 3 and the statistical evaluation is included in Table 4.

Table 3. Data for transport way utilization of vehicles

Identifier of vehicles	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Length of transport way [km]	14644	11528	11608	6380	9963	10394	10488	7449	8000	10234
Distribution	0,16	0,11	0,12	0, 06	0,10	0,10	0,10	0, 07	0,08	0,10

Table 4. Statistical evaluation of transport way utilization of vehicles

Minimal value η_{lmin}	Maximal value η_{lmax}	Expected value $\bar{\eta}_l$	Scattering σ_{η_l}	$\varphi_1 = \sigma_{\eta_l} / \bar{\eta}_l$	$\varphi_2 = \eta_{lmax} / \bar{\eta}_l$	$\varphi_3 = \eta_{lmi} / \bar{\eta}_l$
0, 06	0,16	0,10	0,024	0,222	1,498	0,562

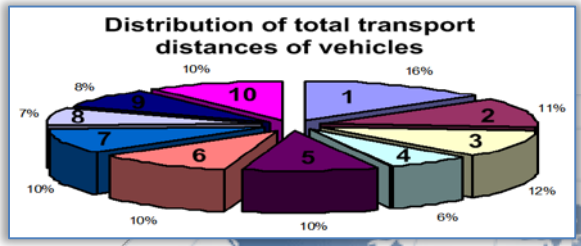


Figure 5. Distribution of total transport distances of vehicles

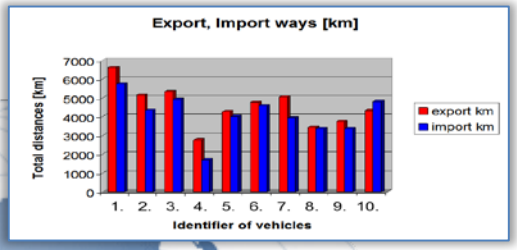


Figure 6. Export and import transport length of vehicles

Total length of a transport way can be divided into the following sections:

$$L_{sum} = L_{Esum} + L_{Isum} + L_{0sum} \tag{3}$$

where: L_{sum} – total transport length, L_{Esum} – total export length (outgoing transport from a given country), L_{Isum} – total import length (incoming transport into a given country), L_{0sum} – way without useful load.

Figure 6 compares the export and import transport length of individual vehicles in a given time interval, Figure 7 shows the distribution of export and import transport length of vehicles.

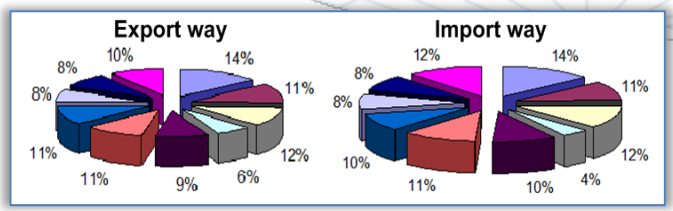


Figure 7. Distribution of export and import transport length of vehicles

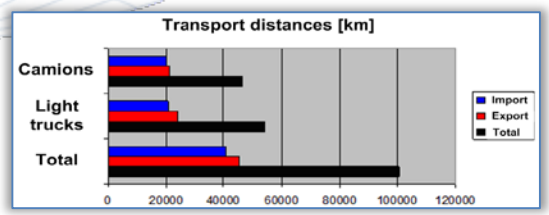


Figure 8. Export and import transport distances of vehicle groups

❖ **Evaluation of transport way utilization of vehicle groups**

Evaluation can be also completed for vehicle groups, the results can be seen in Figure 8.

Weight of freight transported by vehicles

The weight of freight transported by vehicles is the most important and often used indicator for transport activities. The application is also provide the possibility of evaluation of this indicator for vehicles.

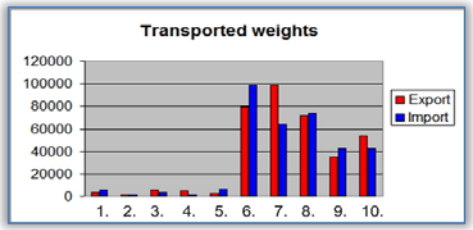


Figure 9. Weight of freight transported by vehicles

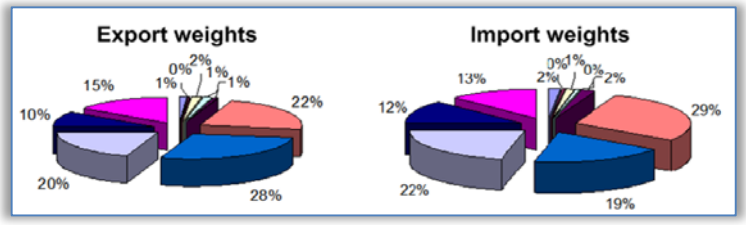


Figure 10. Distribution of export and import freight transported by vehicles

❖ **Evaluation of weights transported by vehicles**

Figure 9 shows the transported weight of freight (in export and import relations) transported by vehicles in a given time interval. Figure 10 plots the distribution of export and import freight transported by vehicles in a given time interval.

❖ **Evaluation of weights transported by vehicle groups**

Figure 11 shows the result of evaluation of transported weights by vehicle groups in the examined time period.

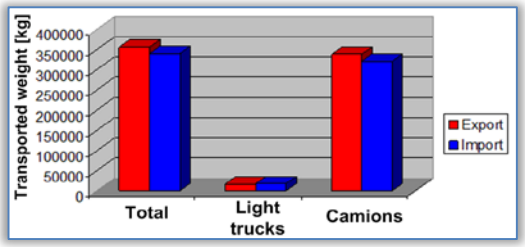


Figure 11. Weights transported by vehicle groups

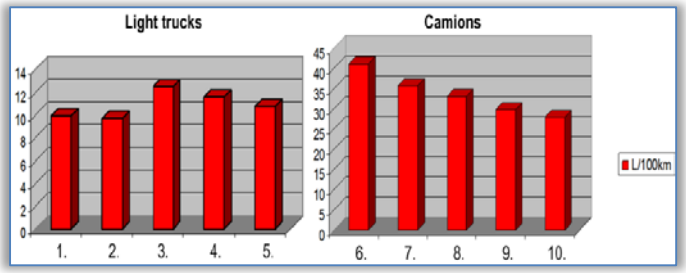


Figure 12. Specific fuel consumption of vehicle categories

Specific and total fuel usage of vehicles

Specific fuel usage of vehicles in a selected time interval can be calculated by the following equation:

$$\eta_{F\,i} = \frac{Q_{T\,i}}{L_{T\,i}} \cdot 100 \quad \left[\frac{liter}{km}\right], \tag{4}$$

where: $\eta_{F\,i}$ – specific fuel usage of vehicles, or vehicle groups, $Q_{T\,i}$ – total fuel usage of vehicles in the given examination time interval [liter], $L_{T\,i}$ – total transport way of vehicles in the given examination time interval [km].

❖ **Evaluation of fuel consumption of vehicles**

Based on equation 4, the specific fuel consumption can be calculated for vehicles (Figure 12) and the statistical evaluation can be also completed (Table 5-8).

Table 5. Data for specific fuel consumption of light trucks

Identifier of vehicles	1.	2.	3.	4.	5.
Specific fuel consumption (l/100km)	9,869	9,677	12,523	11,575	10,749

Table 6. Statistical evaluation of specific fuel consumption of light trucks

Minimal value η_{fmin}	Maximal value η_{fmax}	Expected value $\bar{\eta}_f$	Scattering σ_{η_f}	$\varphi_1 = \sigma_{\eta_f} / \bar{\eta}_f$	$\varphi_2 = \eta_{fmax} / \bar{\eta}_f$	$\varphi_3 = \eta_{fmin} / \bar{\eta}_f$
9,677	12,523	10,878	1,190	0,109	1,151	0,889

Table 7. Data for specific fuel consumption of camions

Identifier of vehicles	6.	7.	8.	9.	10.
Specific fuel consumption (l/100km)	41,126	35,765	33,089	29,820	27,950

Table 8. Statistical evaluation of specific fuel consumption of camions

Minimal value η_{fmin}	Maximal value η_{fmax}	Expected value $\bar{\eta}_f$	Scattering σ_{η_f}	$\varphi_1 = \sigma_{\eta_f} / \bar{\eta}_f$	$\varphi_2 = \eta_{fmax} / \bar{\eta}_f$	$\varphi_3 = \eta_{fmin} / \bar{\eta}_f$
27,950	41,126	33,550	5,191	0,155	1,226	0,833

❖ **Evaluation of fuel consumption of vehicle groups**

Figure 13 shows the specific fuel usage of light trucks and camions in a selected time interval.

We completed the examination of all of the before mentioned logistics indicators for the transport activity of 10 vehicles of a forwarding company based on the available database.

The elaborated method can be widely used at most of small transport or forwarding companies.

Evaluation of logistics indicators can provide useful information because the analysis of historic data provides a real view of the company activity. These data

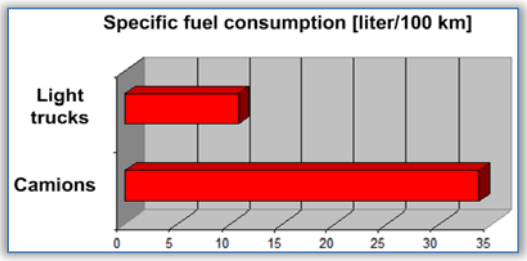


Figure 13. Specific fuel consumption of light trucks and camions

provided by our excel application can help the strategic decision making of general management, optimization of transport processes and making short and long term operative plans.

1. Evaluation of time utilization of vehicles and vehicle groups can provide useful information for:
» efficiency of applied practice for transport trip organization,
» efficiency of activity of the transport manager (who organize and dispose the transport trips),
» investigation of potential wastes of the system (e.g. maintenance problems, etc.).
2. Transport way utilization of vehicles and weight of freight transported by vehicles can provide useful information for:
» efficiency of transport trip organization,
» efficiency of activity of the transport manager.
3. Specific fuel consumption of vehicles can provide useful information for:
» economical operation of the fleet,
» modernization of vehicle fleet.

CONCLUSIONS

Carriers and forwarding agents put great emphasis on the optimization of transportation and reduction of transport costs, because the transportation is one of the most expensive logistical processes. Therefore the optimization of road transport activities can be results a significant cost reduction. This is the reason that this research is important and actual.

A key performance indicator (KPI) is a type of performance measurement. The performance of activities cannot be improved unless it can be measured.

We defined the structure of logistics indicators which can be used for evaluation of the transport activity of a forwarding company. The elaborated method can be widely used at most of small transport or forwarding companies.

Evaluation of logistics indicators relating to forwarding activity can provide useful information because the analysis of historic data provides a real view of the company activity. This information can help the decision making of general management and optimization of short and long term transport activity.

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