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STANDARDIZATION OF A VEHICLE'S POWER EFFECTIVENESS ON THE BASIS OF AN INDICATOR OF SIMILARITY OF SPEED DISTRIBUTION

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Summary. In this thesis there is presented an attempt of standardization of power effectiveness of a truck in conditions of urban agglomeration. The basis of the conducted analysis were tachographs' records of a mean of transport (cold store), used for transport of deep freeze food. In calculations of vehicle's power-intensivity there were used methods of mathematical statistics which enable an assessment of similarity of speed distributions in form of an indicator of similarity.

Key words: vehicle exploitation, cold store transport, power effectiveness of drive, urban agglomeration, mathematical analysis.

INTRODUCTION

Power effectiveness of traffic and agility of a vehicle's propulsion are values deciding on fuel consumption. This value is a basic measure of energetic quality of construction and exploitation. Factors affecting values of particular components of electrical balance are not only specific properties of a vehicle, engine or road, but also pursued speed profile [Siłka 1997].

Characteristic feature of a vehicle's movement in urban agglomeration are periodical changes of speed. Their frequency, scope and intensivity depend on outer factors, dynamic properties of a vehicle and subjective behavior of a driver. Outer factors are road properties (especially elevations), conditions of traffic (time of the day) and atmosphere factors (especially direction and strength of wind falls).

Complex and variable character of influence of the above-named factors causes, that diversified speed profile of a route mainly influences diversified fuel consumption of a vehicle [Siłka 1998]. It concerns also road transport in national and international logistics with variable communication infrastructure [Niziński 2007; Burski i in. 2007].

PURPOSE OF THE THESIS

The purpose of this thesis was using some elements of mathematical statistics (indicators and quotients) in an analysis of distribution of a random variable, which is a profile of vehicle's speed in exploitation conditions of urban agglomeration. A standardization measure of assessment of vehicle's power-intensivity was indicator of similarity of distributions of vehicle's speed (WPR) [Bochniak 2006].

OBJECT AND SUBJECT OF RESEARCH

An object of research was a car-cold store Iveco exploited in transport of deep freeze food from warehouses to reception points (shops) in urban agglomeration (Lublin).

A subject of the research and mathematical analysis were tachographs' recordings (dials) of a profile of vehicle's speed on five consecutive days of the week, in order to obtain statistical validity (average value of a distribution) [Burski i in. 2005 a; 2005 b].

METHODICS OF RESEARCH AND STATISTICAL CALCULATIONS

Methodology of exploitation researches of the vehicle

In standardization researches conducted so far there have been taken into account only stationary road cycles, more or less comparable to exploitation. For urban traffic there is used FUDC test (Federal Urban Driving Cycle), mixed test (urban-road) ECE-EKGUE (in basic and advanced version) or EPA (EPA-Urban, EPA Highway). However, each of them only approximately states the actual traffic conditions. Acceptance of different values of time and length of transit handicaps acquisition of comparative values. The most comparable to the actual driving conditions are so-called complex road cycles (representative) elaborated by American Environment Agency [Siłka 1998].

To development of standardized assessment of power effectiveness of a vehicle in actual exploitation conditions using a speed profile there were used following values of a variable: mean, variance, dispersion, dominant, distribuant of a variable, quotients of alteration and determination, indicator of similarity of values' distributions in consecutive repetitions of 24-hour cycle of vehicle's exploitation.

In the conducted analysis and statistical calculations there were isolated a profile of maximum speed changes (increase of kinetic energy) and a profile of low speed deriving from dispersed kinetic energy as a result of phases of slowing down and braking.

THEORETICAL BASIS OF STATISTICAL CALCULATIONS OF AN INDICATOR OF SIMILARITY OF SPEED PROFILE DISTRIBUTION

Taking into account basic parameters of the distribution of a speed variable as a random variable, a distribution of values of the tested feature *X* may be presented using distribuant (Tab. 1). It states probability – theoretical frequency of occurring in population elements having values equal or smaller than *X*. In general it is expressed by the following formula:

$$F(x) = P(X \le x)\,. \tag{1}$$

Practically, theoretical distribuant of a distribution of the tested feature in population is not known but for a sample took in the conducted experiment it can be estimated. Estimation is also done by construction of a so-called empirical distribuant. For sample order $x_1 \le x_2 \le \ldots \le x_n$ took from considered population (dials), empirical distribuant may be stated as follows:

$$Fn(x)\begin{cases} 0 \quad \text{dla} \quad x \prec x_1 \\ \dfrac{k}{n} \quad \text{dla} \quad x_k \le x \le x_{k=1} \\ 1 \quad \text{dla} \quad x \ge x \end{cases} \qquad (2)$$

It is non-continuous function; there are characteristic leaps of values for the observed value x_k. Usually on horizontal axle there are located values of variable (scopes of speed) and on vertical axle there are values of empirical distribuant – accumulated values. The more elements in a sample (scope of sampling), the less leaps in a diagram of empirical distribuant and this diagram is more similar to a diagram of theoretical distribuant of a distribution from which the sample was taken.

Suggested in the thesis [Bochniak 2006] indicator of variables similarity is based on a field between empirical distribuants for the tested features (here: lost kinetic energy of a vehicle). In case of comparison of two populations (maximum and minimum of a speed profile) estimation of this indicator is done by comparing samples of empirical distribuants (F_1 and F_2). Assuming that Y is a feature in a sample took from the first population (F_1) and Z is a similar feature tested in a sample from the second population. Values of y_j and z_k (j = 1, …, n_1; k = 1, …, n_2) are put on a collective axle in one increasing sequence of values x_i (i = 1, …, n), $n<n_1 + n_2$, for which there are calculated values of empirical distribuants F_1 and F_2, correspondingly for the first and the second sample.

In points x_i, i = 1, …, n-1 there is calculated an absolute value of a difference between distribuants F_1 and F_2: $|F_1(x_i)-F_2(x_i)|$. Difference between distribuants F_1 and F_2 on an interval between two following points x_i and x_i+1 is stated by field of a square with sides with length stated correspondingly by the length of the considered interval x_i+1-x_i and the difference of distribuants' values in point x_i: $|F_1(x_i)-F2(x_i)|$.

Afterwards, overall field of the area contained between distribuants F_1 and F_2 is calculated by summing up of fields of all such squares:

$$P = \sum_{i-1}^{n-1} \left| F_1(x_i) - F_2(x_i) \right| \cdot (x_{i+1} - x_i)\,. \qquad (3)$$

On account of the fact, that while comparing the values of field acquired in this way for various distributions there may occur some difficulties, so it is necessary to normalize their values.

In normalization in terms of a horizontal axle there was used a dispersion of acquired values xi against their common mean X. An average distance of all the observed points, which are below the mean, is calculated by the following formula:

$$D_{\_} = \sqrt{\frac{\sum_{x_1 \prec \bar{x}} (x_i - \vec{X})^2}{n_{\_}}}\,, \qquad (4)$$

where: $n\_$ means a number of values below the mean.

An average distance of points, which are larger than the observed mean (upward standardized deviation), is expressed by the formula:

$$D_{+} = \frac{\sum_{x_i \succ \vec{X}} x_1 - \vec{X})^2}{n_{+}}\,, \qquad (5)$$

where n+ means a number of values larger than mean.

Normalized value can be calculated from the formula:

$$P_u = \frac{P}{D_- + D_+}. \tag{6}$$

Normalization of field value in terms of distribuants' value is not necessary, because their values are in an interval *<0, 1>*, so they can be concerned as normalized.

Bigger field values point to a lesser similarity and lesser point the opposite. In order to reverse this situation and lead to a more natural one – the bigger similarity, the bigger value of an indicator – there has to be done a transformation.

In order to state values of an indicator of distributions similarity (WPR) there was used a following formula:

$$WPR = 1 - P_u\ , \tag{7}$$

granting a mentioned transformation and correlation quotient *ð =100*. The acquired value of an indicator is comparable to the other values, so it allows an evaluation which distributions are more and which are less similar (stating a grade of their similarity).

An indicator is a non-appointed value. Index value is in a scope *<0, 1>.*

In order to state similarity between he compared distributions of feature's values using the suggested indicator of distributions similarity, it is advisable to use the scale from Table 1, as it was presented in the thesis [Bochniak 2006].

Table 1. Scale of distributions' similarity

Value of indicator	Degree of distributions' similarity
<0,9; 1>	Very similar
<0,7; 0,9>	Similar
<0,5; 0,7>	Little similar
<0,3; 0,5>	Very little similar
<0,1; 0,3>	Dissimilar
<0; 0,1>	Highly dissimilar

An assumed scale is conventional. The highest degree of distributions' similarity called "very similar" occurs when the compared samples come from the same distribution with a greater probability. Scale was assumed for samples of 20, 30 elements, when it is possible to make circa 5% statistical error.

RESULTS OF CALCULATIONS AND THEIR ANALYSIS

The results of calculations of time of a vehicle's exploitation and of load out articles from a car made on a basis of speed profile of tachograph diagram are presented in Table 2. In Table 3 there are presented calculations of statistical parameters of distribution of speed profile in five successive days of a vehicle's exploitation.

Table 2. Time of exploitation and waiting of a vehicle in conditions of metropolitan agglomeration in % of 24-hours time of driver's work

No	Lublin	
	Time of drive [%]	Time of waiting [%]
1.	38	62
2.	42	58
3.	34	66
4.	45	55
5.	43	57
Mean	40,4	59,6

Table 3. Summary listing of vehicle's power-intensivity in metropolitan conditions (Lublin)

No	Lublin					
	Mean Km/h		Standard deviation		Variation quotient	
	α	β	α	β	α	β
1.	59,33	18,9	19,14	20,75	0,38	1,09
2.	41,42	6,26	16,0	4,14	0,38	0,66
3.	38,20	16,15	15,0	14,42	0,39	0,89
4.	27,79	11,52	18,32	10,69	0,65	0,92
5.	42,25	8,3	19,64	8,59	0,46	1,03
Mean	39,99	12,22	17,62	11,71	0,45	0,91

α – value of power effectiveness (maximum),
β – value of power effectiveness loss (minimum).

CALCULATIONS OF INDICATOR OF DISTRIBUTIONS' SIMILARITY *WPR*

Calculations of a mean value of distribuant from mean values of particular histogram distributions of speed:

- Mean value $\overline{X}$ is:

$$\overline{X} = \frac{0,315 + 0,419 + 0,277 + 0,215 + 0,338}{5} = 0,312 .$$

- Average surface of area between distribuants F_1 and F_2

$$P = \frac{\sum_{i=1}^{n-1} \left[F_1(x_i) - F_2(x_i) \right]}{n} = 2,693 .$$

- Average distance of points lower than mean value

$$D\_ = \sqrt{\frac{\sum_{x_i \prec x} \left(x_i - \overline{X}\right)^2}{n}} = 0{,}073.$$

- Average distance of points higher than mean value.

- Normalized surface value,

$$D_+ = \sqrt{\frac{\sum_{x_i \succ x} \left(x_i - \overline{X}\right)^2}{n_{(+)}}} = 0{,}063.$$

$$P_u = \frac{P}{(D\_ + D_+) \cdot S_k} = 0{,}196.$$

Where: correlation quotient S_k = *100.*

- Indicator of distributions' similarity *WPR*,

$$WPR = 1 - P_u = 0{,}804.$$

Indicator of distributions' similarity *(WPR)* for metropolitan agglomeration (Lublin) is 0,804, so it reached the level "similar".

CONCLUSIONS

1. Standardization of power effectiveness of vehicles and agricultural machine aggregates is a significant issue in transport and exploitation of agricultural machine aggregates. It concerns not only those countries which have limited material resources with commonly increasing requirement for energy [Burski i in. 2005c, 2005d].
2. In exploitation conditions of vehicles, controlled by tachograph record (with strictly obeyed EU legislation) it seems possible to elaborate standardization of power effectivness based on this record.
3. From an analysis of the subject of the thesis it results that so far norms of power effectiveness, derived from the executed urban and rural road trials with strictly specified traction parameters, do not present the actual conditions of vehicles' exploitation in changeable communication infrastructure of national and international logistics.
4. The executed analysis of the acquired results of calculations (statistical parameters of distribution's probability of speed profile) has shown their repeatability in specific exploitation conditions. According to it, the approved methodoogy in designating an indicator of distributions' similarity may be useful in the standardization process of utilization of a vehicle's energy.

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