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NET WORK AND GROSS WORK IN RAILWAY TRANSPORTATION WITH THE APPLICATION OF CORRELATION THEORY

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Abstract: *The paper deals with net and gross work in railway transportation, and analyzes original data of the "Serbian Railways" company for the last 11 years. The relation between net work and gross work is expressed through net work coefficient and gross work coefficient respectively. Correlation theory is applied to characteristics of net work and gross work, and correlation coefficient and coefficient of determination are calculated.*

Key words: *transportation expenditure, net work, gross work, net ton kilometres, gross ton kilometres, net work coefficient, gross work coefficient, correlation, correlation coefficient, coefficient of determination*

INTRODUCTION

The level of transportation expenditure in railway transportation is influenced by a number of elements that cause bigger or smaller work in transportation organization or implementation. The amount of transportation expenditure for a railway enterprise is regarded as a sum of all separate transportation expenses, while the user of transportation service is interested to know individual transportation charges and the basic elements from which they are formed.

The amount of individual transportation expenses in railway transportation is influenced by the following elements: goods mass or volume, the distance of transportation, the type of goods, net and gross work, the use of railway goods wagons, irregularities in transportation, exploitation conditions, the degree of development and density of the railway network, and transportation volume.

The paper considers the influence of net and gross work on the level of expenditure in railway transportation by applying correlation theory net and gross work marks.

1. NET WORK AND GROSS WORK IN RAILWAY TRANSPORTATION

Goods mass and the distance of transportation are the most authoritative elements for the determination of the amount transportation expenditure. In order to implement transportation of a certain amount of goods at a certain distance it is necessary to implement appropriate useful work, and in railway transportation, it is expressed as net work. Net work is calculated by the following model:

$$R_n = Q_1 \cdot l_1 + Q_2 \cdot l_2 + Q_3 \cdot l_3 + \ldots + Q_n \cdot l_n = NTKM$$

where:
R_n – net work, or useful work, expressed in net ton kilometres (*NTKM*)
Q_1, Q_2, Q_3, Q_n – tons of a certain kind of goods that are transported (*t*)
l_1, l_2, l_3, l_n – distance at which a certain kind of goods is transported (*km*)

The greater goods mass and the longer the distance, the more useful work it is necessary to invest, and vice a versa, the less goods mass and the shorter the distance of transportation, the less useful work it is necessary to invest.

In order to implement social-useful work it is necessary to implement work greater by the mass of wagon, that is, by the mass of railway vehicle employed for transportation of goods. The previous model that expresses net work must be supplemented by the railway wagon mass or by the tare weight respectively, and we will get invested work, which is called gross work in railway transportation. Gross work is calculated by the model:

$$R_b = (q + Q_n) \cdot l_n = GTKM$$

where:
R_b – gross work expressed in gross ton kilometres (*GTKM)*
q – tare weight of the wagon, respectively, its mass (*t*)

Gross work in railway transportation must be larger than net work by the amount made up of work implemented for the transportation of railway wagon mass or a railway vehicle mass.

Besides that, the starting station does not always have empty wagons available for the railway transportation of goods, thus it has to provide goods wagons by delivering them from a certain distant place. The transportation of empty railway wagons requires work to be performed, and the work, though not useful, is unavoidable. Taking into account the performed work, we get a necessary total gross work, which is calculated according to the model:

$$R_b = q\,(1+ \alpha)\, l_n + Q_n \cdot l_n = GTKM$$

where:
α – coefficient of a wagon empty run

By analysing the above given model we can come to the conclusion that $q\,(1+ \alpha)\, l_n$ represents useless work, that is, embraces performed work in the transportation of the mass of empty wagons and loaded wagons, while $Q_n \cdot l_n$ represents useful work.

2. NET AND GROSS WORK IMPLEMENTED BY "SERBIAN RAILWAYS"

Net and gross work, or net ton kilometres and gross ton kilometres respectively, are the main representatives of transportation expenditure in railway transportation, and as has been stated, they depend on a number of elements, or indicators.

In the past eleven years, "Serbian Railways" have realized the following number of net ton and gross ton kilometres:

Table 1. Realized net ton and gross ton kilometres

(10^6)

Indicator	Y e a r s										
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
x_i (*NTKM)*	2398	2538	1190	1917	1989	2263	2591	3164	3482	4232	4570
y_i (*GTKM)*	4135	4680	2402	3589	4032	4600	5235	6339	6934	8184	8570

Source: Public enterprise „Serbian Railways"

During the years under consideration, the total net and gross work, or the total of net ton kilometres and gross ton kilometres respectively, have been implemented: R_n = 30334 *NTKM ;* R_b = 58700 *GTKM.*
The relation of net and gross work has a considerable effect on transportation expenditure. In the total amount of implemented work, a considerable place is occupied by useless work $q\,(1+ \alpha)\, l_n$. The more favourable the relation between gross work and net work is, the less gross work is required to perform a larger amount of net work, which creates a possibility of reducing transportation expenditure.

The relation between net and gross work may be expressed through coefficient of gross work and net work respectively.

Gross work coefficient (Y_b) is calculated according to the following model:

$$Y_b = \frac{R_b}{R_n} = \frac{58700}{30334} = 1{,}94$$

The invested 1, 94 gross ton kilometres implemented one net ton kilometre, or, in other words, for one net ton kilometre it is necessary to invest 94% of useless work because of q and α**.**

Net work coefficient (Y_n) is calculated according to the following model:

$$Y_n = \frac{R_n}{R_b} = \frac{30334}{58700} = 0,52$$

For the implemented 0,52 net ton kilometres, one gross ton kilometre was invested, in other words, for 0,52 net ton kilometres it is necessary to invest 48 % of useless work because of q and α.

Gross work coefficient is always larger than one, while net work coefficient is always smaller than one. The more these coefficients approach one, the less work it is necessary to invest, which results in lower transportation expenditure in railway transportation.

The most important elements that influence the relation of gross and net work in railway transportation are the following:

– the kind of goods with their physical, chemical, technological or other properties;
– suitability of railway goods wagons available to the kinds of goods to be transported;
– technical – exploitation possibilities of railways and stationary facilities and equipment designed for the technology and organization of transportation;
– established organization and technology of transportation adjusted to the requirements of industry;
– arrangement of production and consumer centres, or loaded and unloaded directions in the traffic of goods;
– degree of goods wagon usage.

3. APPLICATION OF CORRELATION THEORY TO PERFORMED NET AND GROSS WORK

Correlation theory studies mutual connections of static characteristics of elements or phenomena and establishes strength of connection, direction of connection and form of connection. Its main indicators are equation of linear simple regression (trend), $y_t = a_0 + a_1 x$, coefficient of determination (r^2), correlation coefficient (**r**), standard error (**S$_y$**) and variation coefficient (**V**). Between implemented net ton and gross ton kilometres there is an appropriate correlation connection with larger or smaller deviations. In the statistical treatment of our example, one characteristic is net ton kilometres: x_i *(NTKM)*, and the other characteristic is gross ton kilometres: y_i *(GTKM)*, and the strength of linear connection is established on the basis of correlation coefficient (**r**) and determination coefficient (r^2).

Correlation coefficient (**r**) is a measure of strength of linear connection, and it takes values between –1 and +1. When correlation coefficient approaches 1, linear connection between characteristics of elements x_i and y_i is strong, and when it approaches 0, there is no linear connection between characteristics of elements x_i and y_i. Correlation coefficient is an unnamed number.

For Pearson correlation coefficient (r) the following rules hold:

$0 < |r| < 0,2$ the connection practically does not exist

$0,2 \leq |r| < 0,5$ shows weak linear connection

$0,5 \leq |r| < 0,75$ shows medium linear connection

$0,75 \leq |r| < 0,95$ shows close linear connection

$0,95 \leq |r| < 1,00$ shows very close linear connection (practically functional)

Pearson correlation coefficient is valid only for linear connection.

Coefficient of determination (r^2) shows the ratio of the total sum squared of explained variation between characteristics x_i and y_i to the total variation, and the amount of variation that remains unexplained as a consequence of the influence of other factors.

The calculated correlation coefficient $r = 0,99$ shows a very close linear connection between implemented net work and gross work of the railway enterprise.

Coefficient of determination is obtained when the value of the obtained correlation coefficient is squared, and it amounts to: $r^2 = 0,98$. The calculated coefficient of determination shows that 98 % of the sum squared of the total variation is explained by the connection between net work (column x_i) and gross work (column y_i), and only 2% of variation remains unexplained, which is a consequence of the influence of some other factors.

Table 2. **Calculation of characteristics of correlation coefficient (r) and coefficient of determination (r^2)**

(10^6)

n Years	x_i (NTKM)	y_i (GTKM)	$X_i = x_i - \bar{x}$	X_i^2	$Y_i = y_i - \bar{y}$	Y_i^2	$X_i Y_i$
1997	2398	4135	-360	129600	-1201	1442401	432360
1998	2538	4680	-220	48400	-656	430336	144320
1999	1190	2402	-1568	2458624	-2934	8608356	4600512
2000	1917	3589	-841	707281	-1747	3052009	1469227
2001	1989	4032	-769	591361	-1304	1700416	1002776
2002	2263	4600	-495	245025	-736	541696	364320
2003	2591	5235	-167	27889	-101	10201	16867
2004	3164	6339	406	164836	1003	1006009	407218
2005	3482	6934	724	524176	1598	2553604	1156952
2006	4232	8184	1474	2172676	2848	8111104	4197952
2007	4570	8570	1812	3283344	3234	10458756	5860008
11	30334	58700	-	10353212	-	37914888	19652512

$$\bar{x} = \frac{\sum x_i}{n} = \frac{30334}{11} \approx 2758 ; \qquad \bar{y} = \frac{\sum y_i}{n} = \frac{58700}{11} \approx 5336$$

Correlation coefficient: $r = \frac{\sum X_i Y_i}{\sqrt{(\sum X_i^2)(\sum Y_i^2)}} = \frac{19652512}{\sqrt{(10353212)(37914888)}} \approx 0{,}99$

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НЕТНА И БРУТНА РАБОТА В ЖЕЛЕЗОПЪТНИТЕ ПРЕВОЗИ С ПРИЛАГАНЕ НА КОРЕЛАЦИОННАТА ТЕОРИЯ

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Резюме: *Докладът разглежда нетната и брутна работата в железопътния транспорт и анализира автентични данни от компанията „Сръбски железници" от последните 11 години. Отношението между нетната и брутна работа се изразява чрез коефициент за нетната работа и съответно за брутната работа Прилага се корелационната теория, за да се характеризират нетната и брутна работа и се изчисляват коефициентите за корелация и детерминация.*

Ключови думи: *транспортни разходи, нетна работа, брутна работа, нето тон/километри, бруто тон/километри, коефициент за нетна работа, коефициент за брутна работа, корелация, корелационен коефициент, детерминационен коефициент.*