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ANALYSIS OF INTERDEPENDENCE BETWEEN AIR TRANSFER OF LC-ITEMS AND GEOGRAPHICAL DISTANCES

ABSTRACT

Using the data collected by the Universal Postal Union, the paper studies the correlation between the delivery time of ordinary mail items by air and the geographical distance. It is found that there is poor linear correlation. The reasons for the obtained results are discussed and a suggestion for improvement is offered, which would mean improvement in the quality of the considered postal service.

KEY WORDS

scatter diagram, standard error, mail delivery time, geographic distance, correlation coefficient

1. INTRODUCTION

LC postal item – is the designation for the category of postal items which includes letters and cards.

The technological process of postal items transfer in postal traffic consists of five basic phases: collection, dispatch, transport, arrival and delivery (handing-in).

Collecting of postal items is the first phase of the technological process of sending postal items between the origin and the destination i.e. the sender and the receiver. By collecting postal items the first stage is performed in concentration of postal items from the sources distributed in space and time, i.e. postal services users.

Dispatch follows the collection of postal items. The task of dispatch is to send all the collected postal items within deadline to the destination post office or towards the destination post.

Postal transport needs to be regarded as a complex system and the process of transferring transport entities by means of various transport means (vehicles) and traffic routes. These are composed of internal transport within the postal facility, transport of postal items as function of concentration, transport of postal items as function of diffusion, transport of postal personnel.

Arrival of postal items to the destination postal hub or destination post office is regarded as the fourth phase of the technological process of postal items transfer. There are two sub-groups of technological procedures that may be distinguished within the arrival phase: receiving and sorting of the received postal items.

The technology of delivering postal items means methods, rules and procedures related to the sorting and handing in the postal items from the post to the addressee. In accordance with the provisions of the regulations on postal services, the postal item can be delivered in several ways, or it can be returned to the sender if undeliverable.

Within the technological process of transferring postal items between the origin and the destination, every postal item passes through all the five mentioned phases. Depending on the time spent in each phase, the transfer time of postal items often deviates from the expected, which is contrary to the basic task of every postal management – minimum time of transfer of postal items, at the same time sustaining quality.

2. THE TASK AND ITS REALISATION

The aim of this work is to study the relationship between the time of postal item transfer and the geographic distance between the considered origin and destination using the theory of correlation. The data have been collected during a several-month-study of ordinary airmail items performed in the Universal Postal Union member countries.

Under the auspices of the umbrella organisation Universal Postal Union, the speed of transferring ordinary airmail items from collection to delivery was

Table 1

Distances between capitals in km				1^{st} control	2^{nd} control	3^{rd} control	4^{th} control	Total	Arithmetic mean
1.	USA	Brazil	7730		10.0	7.9	5.9	23.8	7.9
2.	USA	Venezuela	3317	9.5	10.6		6.6	26.7	8.9
3.	France	Senegal	4223	4.8	4.7	4.5	4.8	18.8	6.3
4.	G.Britain	Brazil	9248		8.0	6.6	5.2	19.8	6.6
5.	Portugal	S.T.&Principe	4562		2.4	6.5	4.8	13.7	4.6
6.	Switzerland	Senegal	4258	3.1	3.5	3.3		9.9	3.3
7.	Germany	Brazil	10001		8.2	5.9	4.7	18.8	6.3
8.	Japan	Brazil	18522		8.9	6.8	6.1	21.8	7.3
9.	Italy	Senegal	4141	8.2	5.6	6.3		20.1	6.7
10.	Spain	Venezuela	6999	11.0	9.6		6.1	26.7	8.9
11.	Germany	Croatia	775	3.6	3.3			6.9	3.5
12.	USA	Croatia	7263			8.3	5.5	13.8	6.9
13.	Canada	Croatia	7069			7.1	5.5	12.6	6.3
14.	Italy	Croatia	536		6.7		4.5	11.2	5.6
15.	Netherlands	Croatia	1098			3.0	3.8	6.8	3.4

studied [7]. The research has been performed on the principle of four separated controls for four different groups of postal items within the same period of time. Due to the availability of data, the research results will be considered for postal managements which provided the most data.

Table 1 shows air distances between capital cities included in the study and the respective duration of transferring ordinary airmail items (with at least two controls) between these cities, expressed in days.

The transfer time of the postal items consists of:

- time from collecting the postal item to dispatch of the postal items from the exchange post office in the country of origin,
- transportation time of the postal item between the exchange post office in the country of origin and country of destination,
- time that a postal item spends at an exchange post office in the country of destination,
- transportation time of the postal item from the exchange post office to the delivery post office,
- time necessary for the delivery of the postal item.

Times shown in Table 1 according to controls are the average times of postal item transfer.

The work will study the relation between two parameters, the distance between the cities and the transfer time of ordinary airmail items.

Generally there is interdependence between the parameters if the increase of one parameter is accompanied by the increase of the other and vice versa. Also, if the increase of one parameter is accompanied by the decrease of the other, and vice versa. In the former case, the direction of relation is positive, and in the latter it is negative. The interdependence between the parameters may also differ with regard to the strength of dependence. The strongest or closest dependence between the parameters is the functional relation. Weaker interdependence between the parameters, which is subject to greater or lesser deviations is correlation or stochastic relation.

Apart from the direction and strength of interdependence, there are also various forms of dependence. The simplest form of the relation is linear relation, as opposed to curvilinear relations. When interrelations of stochastic parameters are studied, the form and direction of the dependence as well as its strength are determined. A set of statistical methods which may be applied to achieve this goal is the theory of correlation. The basic indicators of correlation are the regression equation and the correlation coefficient. The regression curves are matched to the perceived data about the studied parameters, and the correlation coefficient indicates the extent to which the actual data scatter match the regression curve.

Let x_i, $i=1, 2, \ldots, 15$ be the air distance between the cities for which the times of transfer for the ordinary airmail items were measured from collection to delivery from Table 1, y_i the respective arithmetic mean of the transfer times from Table 1. Table 2 shows these data as well as the values that will be used later:

Table 2

i	x_i	y_i	x_i^2	$x_i y_i$	y_i^2	$X = x_i - \bar{x}$	$Y = y_i - \bar{y}$
1	7730	7.9	59752900	61067.0	62.41	1746.8	1.7
2	3317	8.9	11002489	29521.3	79.21	-2666.2	2.7
3	4223	6.3	17833729	26604.9	39.69	-1760.2	0.1
4	9248	6.6	85525504	61036.8	43.56	3264.8	0.4
5	4562	4.6	20811844	20985.2	21.16	-1421.2	-1.6
6	4258	3.3	18130564	14051.4	10.89	-1725.2	-2.9
7	10001	6.3	100020001	63006.3	39.69	4017.8	0.1
8	18522	7.3	343064484	135210.6	53.29	12538.8	1.1
9	4141	6.7	17147881	27744.7	44.89	-1842.2	0.5
10	6999	8.9	48986001	62291.1	79.21	1015.8	2.7
11	775	3.5	600625	2712.5	12.25	-5208.2	-2.7
12	7263	6.9	52751169	50114.7	47.61	1279.8	0.7
13	7069	6.3	49970761	44534.7	39.69	1085.8	0.1
14	536	5.6	287296	3001.6	31.36	-5447.2	-0.6
15	1098	3.4	1205604	3733.2	11.56	-4885.2	-2.8
	$\sum x_i = 89742$ $\bar{x} = 89748/15$ $= 5983.2$	$\sum y_i = 92.5$ $\bar{y} = 92.5/15$ $= 6.2$	$\sum x_i^2 = 827090852$	$\sum x_i y_i = 605616$	$\sum y_i^2 = 616.47$		

The first orientation in the form of a relation between the parameters of air distance between the cities and the airmail transfer times (arithmetic mean of the controls) is provided by the graphical presentation of the pairs of values (x_i, y_i) $i=1,2,\ldots,15$ the so-called scatter diagram. Already the arrangement of points in the scatter diagram allows the direction and type of dependence to be determined, and even to some extent the strength of dependence.

Figure 1 shows the scatter diagram in the given example.

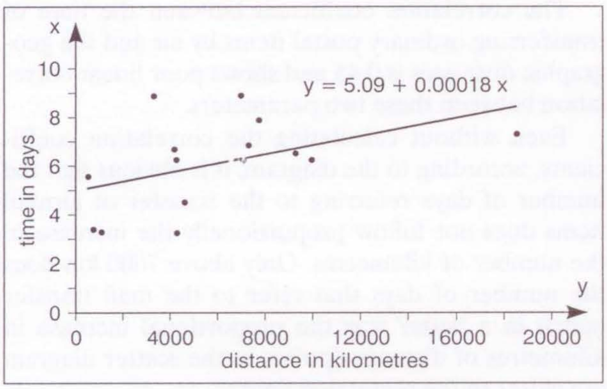

Figure 1 - The scatter diagram

Figure 1 shows that there is a minor positive linear correlation. Let us determine the regression line

$$y = a + bx$$

where:

$$a = \frac{\sum y_i \sum x_i^2 - \sum x_i \sum x_i y_i}{n \sum x_i^2 - (\sum x_i)^2}$$

$$b = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{n \sum x_i^2 - (\sum x_i)^2}$$

By substituting n = 15 and the values obtained in Table 2 into formulas, a = 5.09 and b = 0.00018 are obtained.

The regression line is

$$y = 5.09 + 0.00018x$$

As the measure of accuracy of the estimated time of airmail transfer by means of the regression line, the standard deviation is used, calculated from the deviations of the measured values of y_i airmail transfer times from the estimated values obtained from the regression line equation $y_p = 5.09+0.00018x$. This standard deviation is the mean value of the deviation of the measured data from the regression line and is therefore called the standard regression error. The standard regression error S_y as the value of the dispersion of the points in the scatter diagram about the line of regression has the following form

$$S_y = \sqrt{\frac{\sum (y_i - y_p)^2}{n}}$$

Table 3 presents all the values necessary to determine the standard error S_y.

Table 3

x_i	y_i	y_p	$y_i - y_p$	$(y_i - y_p)^2$
7730	7.9	6.5	1.4	1.96
3317	8.9	5.7	3.2	10.24
4223	6.3	5.9	0.4	0.16
9248	6.6	6.8	-0.2	0.04
4562	4.6	5.9	-1.3	1.69
4258	3.3	5.9	-2.6	6.76
10001	6.3	6.9	-0.6	0.36
18522	7.3	8.4	-1.1	1.21
4141	6.7	5.8	0.9	0.81
6999	8.9	6.3	2.6	6.76
775	3.5	5.2	-1.7	2.89
7263	6.9	6.4	0.5	0.25
7069	6.3	6.4	-0.1	0.01
536	5.6	5.2	0.4	0.16
1098	3.4	5.3	-1.9	3.61
				$\sum = 36.91$

$S_y = 1.58$ is obtained.

Since we start from the assumption that vertical deviations of points from the regression line are distributed according to normal distribution, it may be expected that about 68% of points in the scatter diagram will be located in the track between the lines $y_p - S_y$ and $y_p + S_y$.

Figure 2 shows the track between the lines $y_p - S_y$ and $y_p + S_y$.

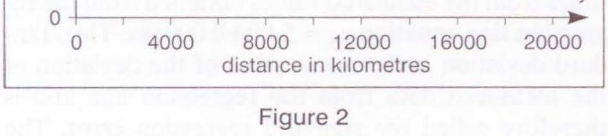

Figure 2

According to Figure 2 we can see that 10 to 15 points lie in the area between the lines $y_p - S_y$ and $y_p + S_y$, that is 67%.

The correlation coefficient

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{(\sum x_i^2)(\sum y_i^2)}}$$

is the measure of the strength of the linear relation and assumes the values between -1 and 1. When the correlation coefficient approaches one, this means that linear dependence between the parameters x and y is strong, and when the correlation coefficient approaches zero, this means that there is no linear dependence between the parameters x and y. However, this does not mean that there is no connection between these parameters, which may even be a strong one but not a linear one.

Table 4 was obtained from the data in Table 2.

Table 4

$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})(y_i - \bar{y})$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$
1746.8	1.7	2969.56	3051310.24	2.89
-2666.2	2.7	-7198.74	7108622.44	7.29
-1760.2	0.1	-176.02	3098304.04	0.01
3264.8	0.4	1305.92	10658919.04	0.16
-1421.2	-1.6	2273.92	2019809.44	2.56
-1725.2	-2.9	5003.08	2976315.04	8.41
4017.8	0.1	401.78	16142716.84	0.01
12538.8	1.1	13792.68	157221505.4	1.21
-1842.2	0.5	-921.1	3393700.84	0.25
1015.8	2.7	2742.66	1031849.64	7.29
-5208.2	-2.7	14062.14	27125347.24	7.29
1279.8	0.7	895.86	1637888.04	0.49
1085.8	0.1	108.58	1178961.64	0.01
-5447.2	-0.6	3268.32	29671987.84	0.36
-4885.2	-2.8	13678.56	23865179.04	7.84
		$\sum = 52207.2$	$\sum = 290182416.8$	$\sum = 6.07$

$r = 0.45$ is obtained.

The correlation coefficient between the time of transferring ordinary postal items by air and the geographic distances is 0.45 and shows poor linear correlation between these two parameters.

Even without calculating the correlation coefficients, according to the diagram, it is obvious that the number of days referring to the transfer of airmail items does not follow proportionally the increase in the number of kilometres. Only above 7000 km does the number of days that refer to the mail transfer match in a better way the proportional increase in kilometres of distance (points in the scatter diagram are closer to the regression line).

There are several reasons for the absence of a stronger linear dependence between these parameters.

One of the reasons is that the phase of the technological process of transferring airmail items which refers to the transport of airmail items (mastering kilometres) between the exchange post offices is short in time compared to other phases. The airmail transport itself between the exchange post offices amounts to an average of less than one day. The longest time in the technological process of transferring airmail items refers to the stay of the items in the exchange post offices of the origin country due to the flight schedule. Depending on the transport schedule, it may happen that the items have to wait even for a few days to get transported.

The second reason that affects the time of airmail item transfer are holidays which make the delivery impossible although the items have reached the exchange post office.

These are then the two reasons due to which the transfer time may be prolonged. This effect is much greater in case of smaller distances.

Because of this it would be interesting to study the correlation between the given parameters by separately analysing the smaller distances and separately the greater ones (over 7000 km).

3. CONCLUSION

The study results have shown that there is poor linear correlation between the mentioned parameters. This was to be expected because the presented data show that the transfer time of airmail items often deviates from the expected times and that these deviations are substantial. It often happens that ordinary mail items reach their destination in a shorter period of time by surface transport, than by air.

However, in order to improve the quality of postal services regarding transfer of postal items, one of the contributing changes would undoubtedly refer to better flight scheduling, which would result in shorter transfer times, but would certainly incur increased costs.

SAŽETAK

ANALIZA POVEZANOSTI IZMEĐU PRIJENOSA LC-POŠILJAKA ZRAČNIM PUTOM I GEOGRAFSKIH UDALJENOSTI

U radu se, koristeći podatke Svjetske poštanske unije, istražuje povezanost vremena prijenosa običnih poštanskih pošiljaka zračnim putom i geografskih udaljenosti. Pokazuje se da postoji slaba linearna korelacijska veza. Diskutiraju se razlozi dobivenog rezultata i daje prijedlog za poboljšanje, što bi značilo poboljšanje kvalitete pružanja promatrane poštanske usluge.

LITERATURE

[1] **Bošnjak, I.**: *Tehnologija poštanskog prometa II*, FPZ, Zagreb, 1999

[2] **Pavlić, I.**: *Statistička teorija i primjena*, Tehnička knjiga, Zagreb, 1988

[3] **Spiegel, M.R.**: *Theory and Problems of Statistics*, 2/Ed., McGraw-Hill Publishing, 1988

[4] **Pauše, Ž.**: *Uvod u matematičku statistiku*, ŠK, Zagreb, 1992

[5] **Kotz, S., Johnson, N. L.**: *Encyclopedia of Statistical Sciences*, Vol. 8, 1981

[6] **Ugrin-Šparac, D.**: *Primijenjena teorija vjerojatnosti*, Elektrotehnički fakultet, Zagreb, 1990

[7] Under the auspices of the umbrella organisation Universal Postal Union, the speed of the transfer of ordinary airmail items from collection to delivery have been studied.