Assessment of Postal Traffic Flows by Means of Measurement System for Transportation Services Transit Times

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Abstract

The paper is focused on usage of methods for assessment of test postal items flows used for measurement of the transit time of end-to-end transportation services for single piece priority mail. The results come out from modelling of measurement of postal transport system efficiency on the basis of real postal traffic flows with particular discriminant characteristics. Measurement of transit time is realized by flow of test postal items in proportion to real postal traffic flows. The result of on-time performance is represented by estimate of on-time probability. The main objective of this paper is assessment of measurement system efficiency by calculation of key parameters for assessment of measurement results from viewpoint of next modelling.

KEY WORDS: *transit time, priority mail, traffic flows, measurement system*

1. Introduction

This paper is focused on usage of methods for assessment of test postal items flows used for measurement of the transit time of end-to-end transportation services for single piece priority mail (SPPM). The results come out from modelling of measurement of postal transport system efficiency on the basis of real postal traffic flows with particular discriminant characteristics. Measurement of transit time is realized by flow of test postal items in proportion to real postal traffic flows. The result of on-time performance is represented by estimate of on-time probability. On-time probability in Czech conditions can be defined as probability of case, when transit time of item does not exceed 1 day ($D+1$). On-time probability is interpreted by variable called weighted estimate of on-time probability, which also includes distribution of mail flows within geographical stratification according to disjunctive set of defined postal areas. The rate of variation caused by used sample design is expressed by quantities of design factor in dependence on considered aspects of sample and measuring system related to sample design and on-time probability estimate.

The main objective of this paper is assessment of measurement system efficiency by calculation of key parameters for assessment of measurement results from viewpoint of next modelling. The results of on-time probability estimate accuracy are related to input assumptions, i.e. especially geographical coverage of postal services and geographical stratification on disjunctive set of postal areas. Modelling methods consider one-Operator field of study with set postal transportation network and considering domestic mail flows for various sample sizes.

2. Measurement System Characteristic

SPPM is collected, processed and delivered by postal operators and measuring process uses representative sample of end-to-end services for addressed mail with set level of service transit time. The total quality of service (QoS) level by transit time is expressed as percentage of end-to-end items distributed during $D+m$ days. Design of QoS measuring system includes selection and allocation of test items. These items are posted and received by selected panellists. Sample design includes specifications of panellists and test items, which must be representative in consideration of design basis. Design basis is the most appropriate structural information available for characterization of real mail distributed in particular field of study.

Transit time of postal item is measured in days and it is expressed as $D+m$ days. Day of posting D is the date of next clearance after induction of item into postal network. The result of QoS is defined by on-time performance. This basic postal performance indicator means percentage of postal items delivered in defined service standard.

The result of on-time performance must be expressed as percentage of postal items delivered in transit time $D+m$, where m represents figure of days determining service standard. Service standard for SPPM in Czech Republic is given by Regulation no. 464/2012 Coll. Relevant part sets, that by measuring of transit times per calendar year there must be achieved result at least 92% of postal mail delivered on the first working day following day of its posting [3]. It means, that at least 92 % of SPPM must have transit time $D+1$. Then service standard (set postal performance level) is at least 92 % SPPM delivered in $D+1$. It is aim of transit time and naturally of on-time performance result as well.

Because measuring of transit times is realized by representative sample of test letters, the result of on-time performance is represented by estimate of on-time probability. On-time probability for test letters can be defined as probability of case, when transit time of test letter flow does not exceed 1 day (*D+1*). On-time probability is interpreted by variable called value of estimate for on-time probability, casely weighted estimate of on-time probability including distribution of letter flows within geographical stratification according to disjunctive set of defined postal areas. The rate of variation caused by used sample design is expressed by design factor from possible viewpoint of unstratified end-to-end measuring system, stratified random sample and stratified end-to-end sample [1]. It is related to sample design and on-time probability estimate. Significant parameters describing exploitation of measuring system are included and characterized in next parts of this paper.

3. Significant Parameters of Measuring System Exploitation

Key parameter of measuring system exploitation is sample variance of on-time probability estimate in end-to-end measuring system $\hat{\text{var}}_{EtE}\left[\hat{p}\right]$ with calculation as follows:

$$\hat{\text{var}}_{EtE}\left[\hat{p}\right]=\frac{1}{n^2}\left[\sum_a\left(x_a-\frac{n_a}{n}x\right)^2+\sum_b\left(x_b-\frac{n_b}{n}x\right)^2-\sum_a\sum_b\left(x_{ab}-\frac{n_{ab}}{n}x\right)^2\right]+ \quad (1)$$

$$+\frac{1}{n^2}\left[\sum_a\sum_b {}_{n_{ab}>1}\, n_{ab}\frac{x_{ab}}{n_{ab}-1}\left(1-\frac{x_{ab}}{n_{ab}}\right)+\sum_a\sum_b {}_{n_{ab}=1}\left\{\frac{1}{4n_a}\frac{x_a}{(n_a-1)}\left(1-\frac{x_a}{n_a}\right)+\frac{1}{4n_b}\frac{x_b}{(n_b-1)}\left(1-\frac{x_b}{n_b}\right)\right\}\right]$$

This parameter includes two elements. The first element is Relation to total variation *RtT*, which represents differences between results of various points of induction and delivery. The second element is Intra relation variation *IRV*, which represents differences between test items in one relation.

Relation to total variation *RtT* consists of two basic components. The first component RtT^I includes aspect of point of induction expressed in following form:

$$RtT^I=\frac{1}{n^2}\sum_a\left(x_a-\frac{n_a}{n}x\right)^2 \quad (2)$$

The second component RtT^D includes aspect of point of delivery expressed in following form:

$$RtT^D=\frac{1}{n^2}\sum_b\left(x_b-\frac{n_b}{n}x\right)^2 \quad (3)$$

Both these expressions are adjusted by expression RtT^{Corr}:

$$RtT^{Corr}=-\frac{1}{n^2}\sum_a\sum_b\left(x_{ab}-\frac{n_{ab}}{n}x\right)^2 \quad (4)$$

In other words, relation to total variation can be divided to three specific components. Difference between mean values of relation and the total mean value RtT_R can be expressed as follows:

$$RtT_R=\sum_a\sum_b\left(\frac{n_{ab}}{n}\right)^2\left(\hat{p}_{ab}-\hat{p}\right)^2 \quad (5)$$

Adjusted difference between mean values of points of induction and the total mean value RtT_I has following form:

$$RtT_I=\sum_a\left(\frac{n_a}{n}\right)^2\left(\hat{p}_a-\hat{p}\right)^2-\sum_a\sum_b\left(\frac{n_{ab}}{n}\right)^2\left(\hat{p}_{ab}-\hat{p}\right)^2 \quad (6)$$

Adjusted difference between mean values of points of delivery and the total mean value RtT_D is determined as follows:

$$RtT_D=\sum_b\left(\frac{n_a}{n}\right)^2\left(\hat{p}_b-\hat{p}\right)^2-\sum_a\sum_b\left(\frac{n_{ab}}{n}\right)^2\left(\hat{p}_{ab}-\hat{p}\right)^2 \quad (7)$$

These separated components of *RtT* provide important reflections of significant contributors to *RtT* and point out the most intense influence and cause on *RtT* – point of induction, point of delivery or certain relations of items flow *R* [1,2].

Intra relation variation *IRV* has calculation form for each relation with more than one valid test item:

$$\hat{\text{var}}_{IRV}\left[\hat{p}_{ab}\right] := \left(\frac{n_{ab}}{n}\right)^2 \hat{\text{var}}_{SRS}\left[\hat{p}_{ab}\right] = \frac{1}{n^2}\frac{n_{ab}^2}{n_{ab}-1}\hat{p}_{ab}\left(1-\hat{p}_{ab}\right) = \tag{8}$$
$$= \frac{1}{n^2}\frac{n_{ab}x_{ab}}{n_{ab}-1}\left(1-\frac{x_{ab}}{n_{ab}}\right)$$

where $\hat{\text{var}}_{SRS}\left[\hat{p}\right]$ is sample variance of simple random sample (*SRS*) generally defined as:

$$\hat{\text{var}}_{SRS}\left[\hat{p}\right] = \frac{1}{n^2}\frac{n}{n-1}x\left(1-\frac{x}{n}\right) \tag{9}$$

For relations of point of induction or point of delivery with only one valid test item it is not possible to calculate *IRV* by way above-mentioned. For these relations with one item following approximation must be used:

$$\hat{\text{var}}_{IRV-OLR}\left[x_{ab}\right] := \frac{1}{4}\left[\frac{1}{n_a^2} * \hat{\text{var}}_{IRV}\left[\hat{p}_a\right] + \frac{1}{n_b^2} * \hat{\text{var}}_{IRV}\left[\hat{p}_b\right]\right] = \tag{10}$$
$$= \frac{1}{4n^2}\left[\frac{x_a}{n_a\left(n_a-1\right)}\left(1-\frac{x_a}{n_a}\right) + \frac{x_b}{n_b\left(n_b-1\right)}\left(1-\frac{x_b}{n_b}\right)\right]$$

here a – index of sender with at least two valid items; b - index of addressee with at least two valid items; ab – index for relation between sender and addressee; n – the number of test items; x - the number of on-time test items; $\hat{p}$ - value of estimate for on-time probability equal x/n; *OLR* – one letter relations.

Calculation method for accuracy can be applied also for results from other measuring systems than SPPM. It is usable for many forms of end-to-end measuring systems, for example bulk mail scenario. There inducted mail volume of one panellist could be sufficiently high for induction to provide partial result adequate to service provided to this panellist. In this case there is necessary to consider only one point of induction. If each point of delivery receives at least two letters, then parameter $\hat{\text{var}}_{EtE}\left[\hat{p}\right]$ has following form:

$$\hat{\text{var}}_{EtE}\left[\hat{p}\right] = \frac{1}{n^2}\left[\sum_b n_b \frac{x_b}{n_b-1}\left(1-\frac{x_b}{n_b}\right)\right] \tag{11}$$

In case of only one letter received by each point of delivery we can speak about simple random sample (*SRS*).

Specific solution must be applied for category of letters within one letter relations (*OLR*). It is case when only some of points of delivery receive exactly one letter and some points of delivery more than one letter. Then parametre $\hat{\text{var}}_{EtE}\left[\hat{p}\right]$ has following form:

$$\hat{\text{var}}_{EtE}\left[\hat{p}\right] = \frac{1}{n^2}\left[n_{OLR}\frac{x_{OLR}}{n_{OLR}-1}\left(1-\frac{x_{OLR}}{n_{OLR}}\right) + \sum_b {}_{n_b>1} n_b \frac{x_b}{n_b-1}\left(1-\frac{x_b}{n_b}\right)\right] \tag{12}$$

The same argument is valid for fields of study with only one point of delivery with form:

$$\hat{\text{var}}_{EtE}\left[\hat{p}\right] = \frac{1}{n^2}\left[n_{OLR}\frac{x_{OLR}}{n_{OLR}-1}\left(1-\frac{x_{OLR}}{n_{OLR}}\right) + \sum_a {}_{n_a>1} n_a \frac{x_a}{n_a-1}\left(1-\frac{x_a}{n_a}\right)\right] \tag{13}$$

In case of accuracy calculation for partial induction results it is possible that certain points of delivery receive only one test item. This fact could be valid e.g. for long-distance letter from special postal area of induction. The consequence of this fact is reflected in *IRV* calculation for one-letter cases. This limitation must be included in *IRV* calculation with adapted final addend in Eq. (1) in the form as follows:

$$\sum_a\sum_b {}_{n_{ab}=1,n_b>1}\left\{\frac{1}{4n_a}\frac{x_a}{\left(n_a-1\right)}\left(1-\frac{x_a}{n_a}\right) + \frac{1}{4n_b}\frac{x_b}{\left(n_b-1\right)}\left(1-\frac{x_b}{n_b}\right)\right\} + \sum_a\sum_b {}_{n_{ab}=1,n_b=1}\left\{\frac{1}{n_a}\frac{x_a}{\left(n_a-1\right)}\left(1-\frac{x_a}{n_a}\right)\right\} \tag{14}$$

For cases of accuracy calculation for partial delivery results the same explanation is valid, for instance long-distance letter to special postal area of delivery [1].

4. Modelling of Test Items Sample and Results of Parameters

Modelling of test items sample is based on parameters of geographical coverage by postal services and stratification of measuring sample for two periods of 2014. Modelling presumes one-Operator field of study with domestic SPPM for various sample sizes in proportion of design basis. Used sample sizes are necessary to cover all postal areas with concrete flows of test items, which must fulfil requirement of proportionality with design basis of real SPPM flows. The first modelling sample considers one-month period, the second one considers two-month period.

Measuring system modelling for both periods is based on relevant indicators figures. These indicators comprised in Table 1 are necessary data for key parameters calculation. Applying these input variables, calculated results of key parameters using above-mentioned equations are contained in Table 2:

Table 1

Input indicators of modelling

Variable	1^{st} period	2^{nd} period
n	1905	5521
x	1796	5085

Table 2

Parameters results of modelling

Parameter	1^{st} period	2^{nd} period
RtT^{I}	2,07001E-05	1,51392E-05
RtT^{D}	6,46072E-05	3,09993E-05
RtT^{Corr}	-2,81814E-05	-1,3376E-05
$\hat{p}$	0,9428	0,9210
$\hat{\mathrm{var}}_{IRV}\left[\hat{p}_{ab}\right]$	2,12842E-07	1,13582E-06
$\hat{\mathrm{var}}_{EtE}\left[\hat{p}\right]$	5,73388E-05	3,38983E-05

Calculated results of key parameters give satisfactory values. Particular elements of *RtT* have very small values with significant contribution of RtT^{D}. Low values have been obtained by *IRV* and $\hat{\mathrm{var}}_{EtE}\left[\hat{p}\right]$ as well. *IRV* values have positively lower level than *RtT* values. Values of $\hat{p}$ meet required postal performance level defined by service standard. Comparing results of 1st and 2nd period, longer 2nd period with larger apllied sample has smaller values of *RtT* and $\hat{\mathrm{var}}_{EtE}\left[\hat{p}\right]$, on the opposite higher value of *IRV*.

5. Conclusions

European Comission emphasizes the necessity to have common rules for development of postal services within Community and improvement of QoS. Comission has defined requirements on postal measuring systems of QoS with possibility of independent end-to-end measurement. The aim of this measurement is to estimate QoS by transit time of end-to-end services for SPPM provided to customer by domestic mail in each European country and by cross-border mail among European countries. Received figures of parameters by measuring system modelling are sufficiently satisfactory. Values of variations are very low and on-time performance meets QoS requirements. Considering applied stratification system of modelled test letter flows, next modelling based on proportional parameters should give reliable results as well.

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