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OPTIMIZATION OF ANALYSIS PROCESS OF E-MONEY PAYMENTS EFFICIENCY

Abstract. This article is devoted to the study and justification of the choice of multiplicative method of forming integral (total) amount of time of customer service to determine the bandwidth of cash desks as more efficient and easy to use, based on the formation of multiplicative assessment function and advantages compared to the additive method. Methods of assessment of construction function – integral index of cash desks bandwidth while using electronic money as means of payment between the customer and the seller of the goods are grounded using specific approaches in analyzing the effectiveness of the electronic money settlement.

Using the toolkit based on the determination of the average value of a particular index in a common set of values for its parameters standardization and mathematical approach to the formation of valuation functions – integral index, which is based on the multiplier approach and the principle of "inversion" of the denominator, it becomes possible to obtain adequate results, which are characterized by clarity of their presentation both graphically and in tabular form.

Keywords: e-money, efficiency**,** multiplicative and additive method, bandwidth, cash desk.

Formulas: 8; fig.: 3; tabl.: 8; bibl.: 12

JEL Classification: B 49, C 52, C 61, C 87, E 51, P 44

Introduction. Analysis of the effectiveness of the project on the use of electronic money for settlements between people and sellers of goods and services should be based on scientifically-based analysis. Thus, investigating the activities of the issuer of legal tender (in Ukraine today – we are talking about banks), performance analysis can be based on a study of the yield of issuing electronic money and the organization of their circulation.

By studying the activity of other entities involved in their circulation, the analysis can be made based on reducing maintenance costs of cash payments after the introduction of electronic money, depending on the social impact that is associated with improvement of cashiers working conditions, etc. This toolkit was studied in our previously published papers [Melnychenko 2015].

In addition, we studied the methods based on queuing theory [Erlang 1909, Palm 1943, Sztrik 2012], which made it possible to assess the effectiveness of implementing electronic money payments in supermarket chains by reducing the amount of time spent at the box office to pay for goods or services and increase cash desks bandwidth by an easier and more rapid method of checkout – electronic money.

In our studies multiplicative method of forming integral (total) amount of time of customer service was used to determine the bandwidth of cash desks as more effective and convenient one to use. In this paper we demonstrate and justify the choices of using an approach that is based on the formation of multiplicative assessment features and advantages compared to additive method.

Literature review and the problem statement. Many works of specialists in various fields are devoted to modeling of economic processes through economic and mathematical methods. Enumeration of each one does not make sense as many authors make their contribution to the development of this very scientific area. Just let us support the great delineation of tools for modeling economic processes by Litvinov A.L. [Litvinov 2003]: mathematical programming, queuing theory, inventory control, game theory. Listed sections make up applied mathematics, methods of which solve critical issues primarily of a practical nature. Each of them plays an important role and gets focused on in the scientific literature. Thus, in our work we stopped in applying methods of queuing theory, which seems logical given the object of our study – electronic money [Melnychenko 2015], which in fact are intended primarily for use in system maintenance [CGAP 2010, Steed 2010].

Features of the application of various methods of economic and mathematical modeling, mathematical approaches that can be used effectively in a particular subject plane (for the class of specific economic problems) and the nuances of their use depending on the purpose of the study, analysis of economic entities objectives and tasks for solution of which the simulations are carried out remain important in this case [Darroch, Speed 1983].

Thus, in our papers we stopped to study the efficiency of implementing electronic money payments by determining the capacity of cash departments and desks as well as its increase through the introduction of electronic money. We proposed to calculate this indicator on the basis of the work of cashiers in terms of asymmetry of data when indicators with different dimensions and different numerical values should be included in the integrated indicator. In this paper, we justify the choice of approach to normalize data for calculations.

Methods of normalization of the indicators are analyzed in the works of authors who also study the identification of problematic situations in banks and there are 4 of them in general [Trydid, Samorodov, Goykhman 2014], outlining in particular:

- average value of a particular index in a common set of its values;
- standard deviation of actual values;
- approach "better – worse";
- values of column–vector norms in determining the normalized values of indicators.

The authors distinguish such approaches to the calculation of integral indicators:

1. Additive approach – the sum of normalized values of indicators.
2. Multiplier approach – the multiplication of normalized values.
3. Determination of the Euclidean distances between the actual values of the indicators.

Note that normalized values of indicators that are measured and on which estimate function is based may be corrected for the weighted coefficients of corresponding importance if needed [Samorodov 2011; Samorodov, Trydid, Samorodov 2012].

In these works, the authors assess the adequacy of proposed methods based on theoretical data. We are taking these approaches and sharing views on the possibility of their use in the analysis of banking activities, make comparisons of appropriateness and objectivity of using two of them, namely additive and multiplicative integral factor in analyzing the effectiveness of the electronic money settlements. As methodological approach used for normalization of the studied parameters, we choose one that is based on the definition of the average value of a particular index in a common set of its values.

The purpose of this paper is to study methods of the assessment function construction – the integral index, which characterizes the total time of customer service to determine the cash desks bandwidth when using electronic money as means of payment between the customer and the seller of goods and substantiate use of these methods in analyzing the effectiveness of the electronic money settlement.

Research results. So, as we noted in [Melnychenko 2015] practical cash desks bandwidth μ_{pract} should be calculated using the following relationship:

$$\mu_{pract} = \frac{NC}{TR(LQ, OP) + TP(AP, FP, AC, LQ, AL, OP) + TI(PI, OP)}, \qquad (1)$$

where NC – the number of clients that "passed" through the cash desk;
TR(LQ, OP) – time required for customer service (taking applications for processing, document preparation, etc.);
LQ – level of cashier qualification;
OP – other parameters;
TP(AP,FP,AC,AL,CA,OP) – time for payment of the customer;
AP – amount paid;
FP – form of payment (cash or bank transfer);
AC – amount of cash – banknotes and coins that are transferred from the payer to the cashier and vice versa;
AL – cash desk automation level;
TI(PI,OP) – cashier idle time;
PI – the probability of receipt incoming.

Value of μ_{pract} will be calculated precisely because of the normalization of the data for one of the above algorithms. In [Melnychenko 2015] we used a multiplier approach to calculation of the integral index and the average value of a particular index in a common set of values for its normalization of values of indicators as the most appropriate for the task: evaluation of cash desks bandwidth. Below we justify the selection of this instrument.

Based on the data of one of the supermarkets in Poland table 1 shows the average productivity of cashiers for 3 days (except for values of indicators "Payment", "Quantity of cash", "Cash desks automation level", "The probability of receipt of the application for service" "Other factors" which are defined empirically). The survey sampling comprised 109 man–days, in which customers purchased goods worth a total of 1 531 226.29 PLN.

For greater clarity of our calculations in this article, we took the average values in the context of the studied days and will operate with three average ones instead of 109.

To give some explanation of the indicators listed in the table 1 and determined empirically:

1. Form of payment:

– cash, which includes the likelihood of the need to issue the residue back to the client, takes more time for a re–calculation and double–checking.;

– bank transfer, credit or debit card, electronic money that will not require the issuance of the residue back to the client.

We propose to determine the value of FP, it may take:

– FP = 1, if there is a need to use cash for the payment and to issue the residue back to the client;

– FP = 0,8 if payment is made by means of cash with consequences mentioned in p. 1 above, or a bank card with the need to enter a PIN or sign the receipt, as well as by means of e-money;

FP = 0,5 if payment is processed only by means of bank cards and e-money.

Table 1 – Performance of supermarket cashiers

Indicator	Average value	Average value per day		
		17.12.2014	**21.12.2014**	**22.12.2014**
Turnover, PLN	15 119,62	11 687,17	16 781,23	16 890,46
Form of payment	0,80	0,80	0,80	0,80
Quantity of cash	20,00	20,00	20,00	20,00
Cash desk automation level	0,80	0,80	0,80	0,80
The probability of receipt incoming	0,92	0,85	0,95	0,95
Scan time, hours	2:19:07	1:44:42	2:31:20	2:41:18
Payment time, hours	1:33:07	1:27:14	1:35:12	1:36:54
Other factors	1,00	1,00	1,00	1,00
Number of clients	130,00	131	130	129

Source: built on the basis of our own research

2. Amounts of cash. Clearly, any cash denomination is accepted as payment means, so it is probable that the customer can pay, for example, 500 monetary units as one banknote, maybe 10 banknotes fifty each, or 500 banknotes and/or coins and more. Also, when buying something cheap customer can pay with large denominations (100, 200, 500 monetary units).

The approximate average value of the amount of cash that the buyer is using equals to 20 pieces of banknotes and coins.

3. Cash desk automation level. The speed of the cashier when taking money and when issuing the rest for the client depends on setting up an information system in general as well as on the software which runs a particular cash desk, same for the availability of machines for counting banknotes and coins and on their class and specification.

The workstation level software for cashiers today can be considered as high, given that many of the functions are performed automatically. For example, bank cashiers do not need to calculate bank commission on payments received from customers or write the same type of documents or make accounting entries in the accounts. In supermarkets, in most cases, the cashier does not have to enter code for a specific good or make transactions with cards when paying manually. All these operations are carried out by automated systems. However, there is still a need, for example, in calculation and issuance of the residue for clients, issuing checks, receipts, etc. Therefore, the cash desk automation level is defined at 0.8, which is considered a reduction factor due to a need of a cashier's manual work.

Other factors can, in particular, include: possible faults in cashiers equipment, rate of change checks by customers, delays associated with the provision of cash desk (cash, securities, etc.), etc. In our case, the index takes value of 1 (there are other factors) or 0 (other factors do not affect the cash desk bandwidth).

So, going directly to calculation of values of cash desk bandwidth integrated indicators, it should be noted that the definition of normalized values of performance appraisal will use the formula:

$$Ind'^{(t)}_i = \frac{Ind^{(t)}_i}{\overline{Ind}^{(t)}_i}, \tag{2}$$

where $Ind'^{(t)}_i$ – normalized values of indicators; $Ind^{(t)}_i$ – actual values of indicators; $\overline{Ind}^{(t)}_i = \frac{1}{T}\sum_{t=1}^{T} Ind^{(t)}_i$ – average values for every analyzed time period; $i = \overline{1,n}$ – indicator number; n – quantity of indicators; $t = \overline{1,T}$ – time period number; T – quantity of time periods.

To calculate the numerical values of the equation denominator (1) we will use two approaches.

The first approach is based on the use of formulas:

$$\mu_{pract} = \frac{NC}{TR(LQ,OP) \cdot TP(AP,FP,AC,LQ,AL,OP) \cdot TI(PI,OP)} = \frac{NC}{I^{(t)}} = \frac{NC}{\prod_{i=1}^{7} Ind'^{(t)}_i}, \tag{3}$$

$$\mu_{pract} = \frac{NC}{TR(LQ,OP) + TP(AP,FP,AC,LQ,AL,OP) + TI(PI,OP)} = \frac{NC}{I^{(t)}} = \frac{NC}{\sum_{i=1}^{7} Ind'^{(t)}_i}, \tag{4}$$

That is, in the case of formula (3) we calculate multiplicative integral indicator to determine the numerical value of the equation denominator (1) including all of its components together, and using the formula (4) – additive integral indicator.

The second approach will consist in calculating the corresponding components of the denominator in the formula of (1) for each component: TR (time for customer service), TP (payment processing time) and TI (cashier idle time), using the same approach – multiplicative and additive integral indicators. That is, in this case, the following formula should be used:

$$\mu_{pract} = \frac{NC}{TR(LQ,OP) + TP(AP,FP,AC,LQ,AL,OP) + TI(PI,OP)} = \frac{NC}{I_1^{(t)} + I_2^{(t)} + I_3^{(t)}} = \frac{NC}{\prod_{i=1}^{2} Ind_i'^{(t)} + \prod_{i=1}^{6} Ind_i'^{(t)} + \prod_{i=1}^{2} Ind_i'^{(t)}}, \quad (5)$$

$$\mu_{pract} = \frac{NC}{TR(LQ,OP) + TP(AP,FP,AC,LQ,AL,OP) + TI(PI,OP)} = \frac{NC}{I_1^{(t)} + I_2^{(t)} + I_3^{(t)}} = \frac{NC}{\sum_{i=1}^{2} Ind_i'^{(t)} + \sum_{i=1}^{6} Ind_i'^{(t)} + \sum_{i=1}^{2} Ind_i'^{(t)}}, \quad (6)$$

First, we will demonstrate the adequacy of the results that may be obtained using formulas (3) – (6) for conventional data close to real one (table 2).

We propose to simulate a situation where the results of the same cash desk workflow are constant for all three days selected (table 3).

Table 2 –Input data (identical) to verify the adequacy of the proposed models

Indicator	Average value	Average value per day		
		17.12.2014	21.12.2014	22.12.2014
Turnover, PLN	16 781,23	16 781,23	16 781,23	16 781,23
Form of payment	0,80	0,80	0,80	0,80
Quantity of cash	20,00	20,00	20,00	20,00
Cash desk automation level	0,80	0,80	0,80	0,80
The probability of receipt incoming	0,95	0,95	0,95	0,95
Scan time, hours	1:44:42	1:44:42	1:44:42	1:44:42
Payment time, hours	1:27:14	1:27:14	1:27:14	1:27:14
Other factors	1,00	1,00	1,00	1,00
Number of clients	130,00	130	130	130

Source: built on the basis of our own research

Table 3 – Modeling of indicator $\mu_{pract}^{(t)}$ for the same input data of cash desk

Indicator name	Integral criteria type	Formula used for calculation	Average value per day		
			17.12.2014	21.12.2014	22.12.2014
Value $\mu_{pract}^{(t)}$	Multiplicative	(3)	1	1	1
	Additive	(4)	0,125	0,125	0,125
	Multiplicative	(5)	0,33333333	0,3333333	0,3333333
	Additive	(6)	0,08333333	0,0833333	0,0833333

Source: built on the basis of our own research

Table 3 shows the calculations obtained using formulas (3) – (6) for the input data from table 2, and it is clear that the calculation of values of indicator μ_{pract} by formulas (3) – (6) we obtained the same qualitative values.

Let's complicate the task, and model the situation in which we get one worst period characterized accordingly by a worst (minimum) indicator value of $\mu^{(t)}_{pract}$ cash desk bandwidth. Input data is mentioned in table 4.

Table 4 – Input data (different) to verify adequacy of the proposed models

Indicator	**Average value**	**Average value per day**		
		17.12.2014	**21.12.2014**	**22.12.2014**
Turnover, PLN	16 781,23	16 781,23	16 781,23	16 781,23
Form of payment	0,80	0,80	0,80	0,80
Quantity of cash	20,00	20,00	20,00	20,00
Cash desk automation level	0,80	0,80	0,80	0,80
The probability of receipt incoming	0,95	0,95	0,95	0,95
Scan time, hours	2:04:42	2:44:42	1:44:42	1:44:42
Payment time, hours	1:47:14	2:27:14	1:27:14	1:27:14
Other factors	1,00	1,00	1,00	1,00
Number of clients	130,00	130	130	130

Source: built on the basis of our own research

Table 4 shows that the scan time and payment time for the first time period are different from the corresponding values for the other studied periods. The values of every other parameters are the same.

Table 5 contains calculations obtained after using formulas (3)–(6) for input dates of table 4.

Table 5 – Modeling indicator $\mu^{(t)}_{pract}$ for different input of cash desk

Indicator name	**Integral criteria type**	**Formula used for calculation**	**Average value per day**		
			17.12.2014	**21.12.2014**	**22.12.2014**
Value $\mu^{(t)}_{pract}$	Multiplicative	(3)	1,81342771	0,68302440	0,68302440
	Additive	(4)	0,13359230	0,11876086	0,11876086
	Multiplicative	(5)	0,47553745	0,2545726	0,2545726
	Additive	(6)	0,09115003	0,0778782	0,0778782

Source: built on the basis of our own research

Table 5 shows that carrying out calculations of indicator values $\mu^{(t)}_{pract}$ gives same qualitative results. However, if we analyze their relevance, we see that the results do not correspond with reality. The results should have indicated the lowest cash desk bandwidth as of 17.12.2014, since that day scanning time was equal to 2:44:42, while payment time was 2:27:14, both being worst results compared to other days, accordingly it would adversely affect the value of $\mu_{pract}^{(t)}$.

Here, the root cause lies in the essence of integrated criteria used for denominator calculation in (3) – (6), namely being the accumulation of values in a situation of "more is better". However, realizing the fact that the maximum cash desk bandwidth:

$$\mu_{max} = \frac{NC}{TR_{min} + TP_{min} + TI_{min}}, \qquad (7)$$

is a functional, in which the denominator is reduced in absolute terms, we should revert its value.

In this case we will have for the general indicator $\mu_{pract}^{(t)}$, the following formula:

$$\mu_{max} = \frac{NC}{\left(TR + TP + TI\right)^{-1}} = NC \cdot \left(TR + TP + TI\right). \qquad (8)$$

When using the formula (8) the result should not be understood as the number of customers over the same period of time but as the time required for servicing a certain number of customers.

Using formula (8) for data from table 5, we get the following results (see table 6).

Table 6 shows the results adequacy, thus we should consider formula (8) being a proper one.

Table 6 – Modeling of $\mu_{pract}^{(t)}$, for different input data with inversion

Indicator name	Integral criteria type	Formula used for calculation	Average value per day		
			17.12.2014	21.12.2014	22.12.2014
Value $\mu_{pract}^{(t)}$	Multiplicative	(3)	0,55144188	1,46407653	1,46407653
	Additive	(4)	7,48546130	8,42028196	8,42028196
	Multiplicative	(5)	2,10288377	3,9281531	3,9281531
	Additive	(6)	10,9709226	12,840564	12,840564

Source: built on the basis of our own research

The next stage of the study is the determination of a specific approach that most appropriately reflects the results in solving economic problems of this class.

Let us analyze graphical form of results obtained in table 6 (Fig. 1, 2).

From fig. 1, 2 and the data from table 6 it is obvious that the results differ quantitatively with the same quality. Therefore, in this case we should firstly decide which formulas to choose for calculation of . We propose to stop at this point in formulas (5) and (6) due to the fact that they completely describe the structure of time-consuming, with each cost of time function calculated separately as part of the denominator of the formula (1) (check formula (7) as well).

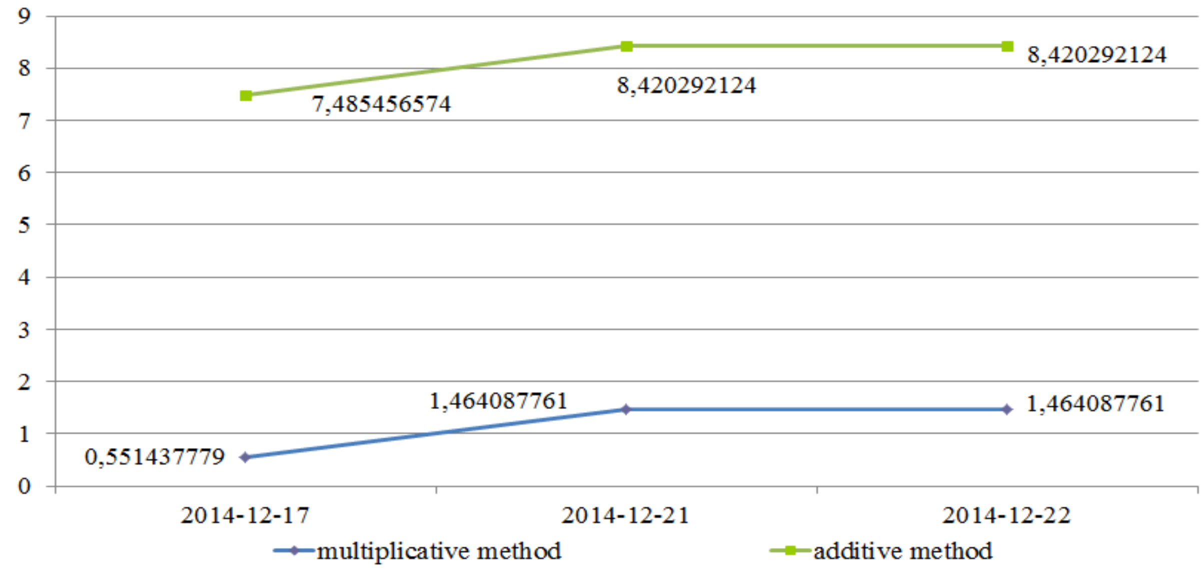

Figure 1 – Graphical interpretation of $\mu_{pract}^{(t)}$, calculated by formulas (3)–(4) with an inversion used

Source: built on the basis of our own research

Regarding grounded recommendations of using a particular approach to an integral parameter construction (additive or multiplicative), you should explore the relative change of values of $\mu_{pract}^{(t)}$. Relative change in this case is important for visualization of the results. Note that we explore only three time periods and thus it is graphically identifiable on which date we have better results of $\mu_{pract}^{(t)}$. With the growing number of periods analyzed results will inevitably match in quality, but visually they will be difficult to analyze.

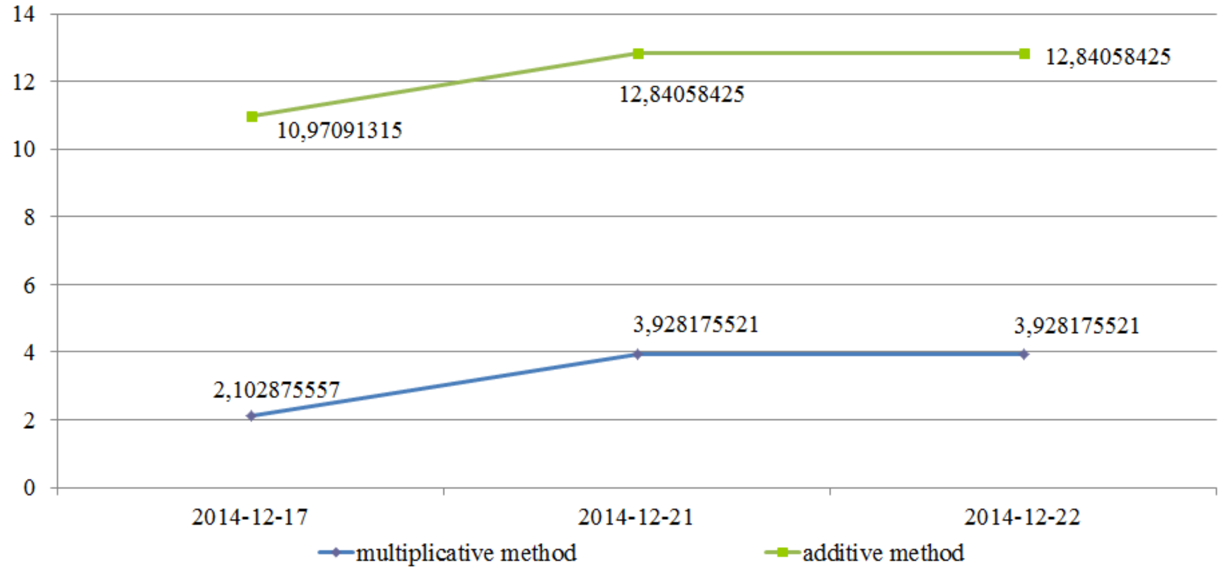

Figure 2 – Graphical interpretation of $\mu_{pract}^{(t)}$, calculated by formulas (5)–(6) with an inversion used

Source: built on the basis of our own research

Lets analyse relative changes of $\mu_{pract}^{(t)}$, based on formulas (5) and (6) according to (8). Results are shown in table 7.

Table 7 – Relative changes of $\mu_{pract}^{(t)}$

Indicator name	Integral criteria type	Formula used for calculation	Average value per day		
			17.12.2014	21.12.2014	22.12.2014
Value $\mu_{pract}^{(t)}$	Multiplicative	(5)	–	86,7983916	0
	Additive	(6)	–	17,0417876	0

Source: built on the basis of our own research

Table 7 shows that quantitatively the relative change in value of the index $\mu_{pract}^{(t)}$ is bigger while using multiplicative approach to integrated parameter construction. Using this approach will allow to obtain results that can be analyzed in a more convenient way by increasing the number of analyzed periods.

So we reasonably chose a tool the use of which is not only possible when analyzing the efficiency of payments by electronic money, but also allows you to get adequate results which are characterized by clarity of their presentation both graphically and in tabular form.

Using the selected tool based on the determination of the average value of a particular indicator in a common set of values for its standardization parameters (formula (2)), as well as mathematical approach to the formation of the assessment function – integral index, based on multiplicative approach (formula (5)), and denominator inversion (formula (8)), we will calculate value of practical cash desk bandwidth $\mu_{pract}^{(t)}$ using table 1 – real data. Results are shown in table 8.

Table 8 – Calculation of $\mu_{pract}^{(t)}$ for real data

Name of indicator	Integral criteria type	Formula used for calculation	Average value per day		
			17.12.2014	21.12.2014	22.12.2014
Indicator $\mu_{pract}^{(t)}$	Multiplicative	(5)	3,4682047	2,9333085	2,7693844
Relative changes of $\mu_{pract}^{(t)}$			–	– 15,422854	– 5,5883715

Source: built on the basis of our own research

Graphical interpretation of calculation of $\mu_{pract}^{(t)}$ for real data is shown on fig. 3.

Table 8 and figure 3 show that best results of cash desk bandwidth were obtained on 17.12.2014.

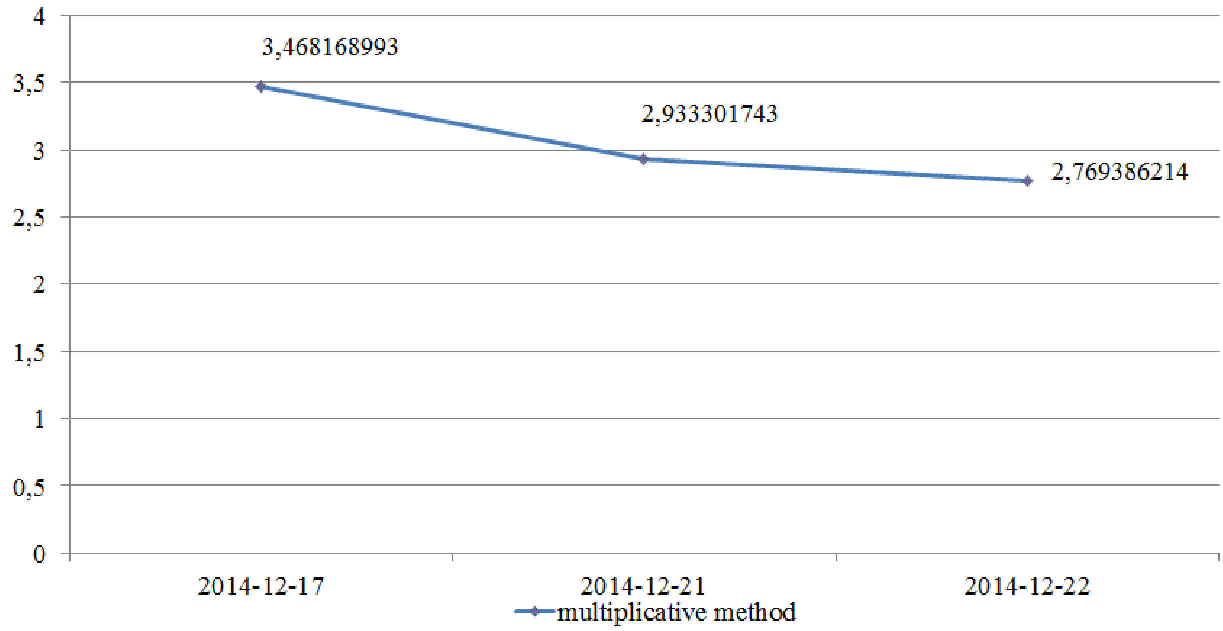

Figure 3 – Graphical form of $\mu_{pract}^{(t)}$, using formula (5) and inversion

Source: built on the basis of our own research

Obtained maximum is primarily characterized by minimal time to scan and process the payment, despite the fact that turnover during this day is minimal compared to other time periods studied.

Conclusions. Research of methods for constructing the assessment function – integral index, which characterizes the total time of customer service to determine the cash desk bandwidth using electronic money as means of payment between the customer and the seller of goods made the justification of the use of specific approaches in analyzing the effectiveness of the electronic money settlements possible.

Using tools based on the determination of the average value of a particular indicator in a common set of values for its standardization parameters (formula (2)), as well as mathematical approach to the assessment functions formation – integral index, which is based on the multiplier approach (formula (5)), using the denominator inversion (formula (8)), gives adequate results, which are characterized by clarity of their presentation both graphically and in tabular form.

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