Influence of information integrity control of the unified model of the automated information system of commercial enterprises on conditional profit

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Abstract. Unified model of the automated information data system (AIS) at the commercial enterprises (UMAIS CE) as a protected AIS for the provision of the commercial activity of the enterprises with the common structure and configuration of equipment is examined in the article. Information integrity control (IIC) is an integral part of this model, and its functioning has an impact on the contingent profit of the commercial enterprise considered in the frameworks of UMAIS CE. Mathematical model of IIC UMAIS CE presented within this context, just as a number of computing experiment that allow determining of a strategy of the effective usage of IIC UMAIS CE and specified ways for increase of the contingent profit at the commercial enterprise.

1. Scope of the problem

Commercial enterprise (CE) is a juridical profit-seeking entity as a main objective of its activity and sharing it between its members – founders and employees. In most cases the main kind of its activity is a sales of products and (or) services.

For the purposes of most efficient organization of its activity CE does actively apply automated information data system (AIS). AIS is a system consisting of the personnel and a complex of automation devices of its activity that are required for the execution of its functions with the use of the information technologies.

Security of the information that is processed in AIS CE is required because it may involve commercial classified information and/or personal data. Standard acts regulating measures on the protection of such information are presented in the Federal law accepted on 29.07.2004 № 98-FL (Ed. on 18.04.2018) «On the commercial classified information» and Federal law on 27.07.2006 № 152-FL (Ed. on 31.12.2017) «On the personal data».

Analysis of systemic and applied software employed in AIS CE demonstrated that in this software, as a rule, there are a lot of vulnerabilities. In this situation it is possible to get the presence of “zero day” vulnerabilities, and the information on these vulnerabilities is absent in the corresponding data bases, for example, in CVE data base. It is also characterized by the absence of non-declared facilities [1], thus stipulating a high probability of realization a number of threats to the information security directed as
on the theft of information containing the data related to the commercial classified data as on the break of operation of software and hardware components. Main shortcomings of the typical utility intended for the integrity control of the considered AIS revealed during operation of the system comprise in the inability to counteract an attack (in fact, only the event of presence of such attack), the absence recovery means after unauthorized modification of the information and the absence of a convenient interface for the interaction of AIS administrator with the utility. With the account of the quantitative and qualitative growth of the number of threats for the information security of AIS CE it was proposed to develop the latter on the basis of the reference model of the protected automated system (RMPAS) which regulates security model (SM) providing flexible, convenient and secure differentiation of access to the data. RMPAS is presented in [2].

In RMPAS organization of the control for integrity of the information (CII) is different by initialization of the control checkout at each level of RMPAS for each discretion level thus reducing efficiency of the clients’ service and thus, the contingent profit of CE. Therefore, for the adaptation of CII RMPAS its optimization is required directed at the increase of the contingent profit of CE under a sufficient control level.

In fact, for the adaptation of RMPAS to the specific features of AIS CW it is required to have also the development of the corresponding model of CII. To make this let us consider the unified model of the automated informational system of commercial enterprises (UMAIS CE) as a model of AIS CE as protected AIS CE with the generalized structure and configuration of equipment that provides versatility of the obtained results.

UMAIS CE is characterized by the presence of the control for information integrity (CII) which is the element of subsystem, providing integrity of the operational environment (software tools and processed data). CII is a tool for testing of the operational environment and it is intended for a periodical comparison of its current state with the reference one.

The aim of our work is to present the results of computing experiments based on mathematical model of CII UMAIS CE allowing determination of a strategy for the efficient use of CII UMAIS CE and certain ways to increase the contingent profit of a commercial enterprise.

In order to develop mathematical model of CII UMAIS CE let us use criteria for the quality of its functioning, allowing to perform optimization directed at the maximum profit earning of CE but under sufficient control. They were specially developed for the adaptation of CII RMPAS to specific features of CE. The main of them is comprised in a necessity to get contingent profit by CE. The aim of the control of CII service is the same for different AIS – support of a reasonable trade-off between meeting the claims to AIS concerning informational security and requirements according to its mission.

According to [2], the following characteristics are applied for CII RMPAS which are divided by the following criteria:

- Efficiency of CII means its ability to provide the control for the integrity of information to be checked-out. A criterion of this characteristic is functionality of CII \( D_f \), that corresponds to the completeness of its set of functions from the viewpoint of using it as a software facility.
- Aggressivity of CII is its ability to support the needed level of efficiency for UMAIS SE relative to its mission. The criteria of this characteristic are: resource aggressivity of CII \( D_{pa} \) meaning an additional consumption of the hardware resources and functional aggressivity of CII \( D_{fa} \) – compatibility of CII with the technology of the information in UMAIS CE system.
- An ease of using CII \( D_y \) – ae the efforts of the personnel required for support of its functioning.

Two new criteria different by their scientific novelty are presented below. They are described in details in [3].

- Contingent profit \( D_{p} \) is a criterion demonstrating an average profit from the received order of a customer. It allows to control the effect of additional time consumption resource for the contingent profit of CII. It is involved in the aggressiveness of CII characteristic.
Sufficiency of the control for integrity ($D_{dkc}$) – a criterion that corresponds to the ability of CII UMAIS CE to perform the execution of the specified CII functions. It is involved in the characteristics of CII efficiency.

The first four criteria are named as statistical ones. They possess Boolean values: «1» is an acceptable quality control, while «0» is an unacceptable one. These new criteria are called dynamical ones. Their results do always take positive values. The greater value of anyone among them is usually interpreted as a best quality of CII by the given criterion. Therefore, the problem of optimization for CII UMAIS CE can be written as follows:

$$D_n(s) \rightarrow \max,$$

for $D_{dkc}(s) \geq D_{dkc}, D_f(s) = D_{pa}(s) = D_{fa}(s) = D_y(s) = 1$  \hspace{1cm} (1)

Probabilistic model is then considered that is intended for the analysis of dynamic criteria of CII UMAIS CE that will be an absorbing CEE. It will be associated with the transitions between UMAIS CE levels where the resources are shared under hierarchical restructuring [4] that is regulated by RMPAS. Initial state of CEE corresponds to the start of CII after authorization of a discretion access – dwelling at the identification level. Final state implies getting access to the data – dwelling at the informational level. For details see [5].

Let us introduce a criterion of dynamic efficiency of CII that can be used for expression of the dynamic criteria:

$$D(t_m) = P\left(t_{dd} \leq t_{\max}\left(t_m\right)\right), \text{ then}$$

$$D_n = \Pi_s \cdot P\left(K_{(dd)} \leq K_{(dd)\max}\right) = \Pi_s \cdot P\left(t_{(dd)} \leq t_{\max n}\right) = \Pi_s \cdot D(t_{mn}),$$

$$D_{dkc} = P\left(K_{(dd)} > K_{(dd)\min}\right) = 1 - P\left(t_{(dd)} \leq t_{\min dkc}\right) = 1 - D\left(t_{tdkc}\right). \hspace{1cm} (3)$$

Below the following definitions are given.

$\Pi_s$ – expectation value of the profit from the regular incoming order in case of its practical ordering calculated on the basis of data on the sale for the previous periods of time.

$t_{(dd)}$ – random value of the total time of CII proceeding during the common discretionary access of the certain order.

$t_{\max n}$ – maximum permissible limit of the time for II proceeding in the process of the common discretionary access for a certain order. It is a random value with the exponential distribution having mean value of $t_{mn}$ and it means maximal time of the client expectation after which the order will be removed.

$K_{(dd)}$ – CII coefficient in the process of the whole discretionary access;

$t_{\min dkc}, K_{(dd)\min}, K_{(dd)\max}$ – minimal and maximal permissible limits for the corresponding values which are exponentially distributed in accordance with the corresponding mean values of $t_{tdkc}$,

$K_{(dd)\min}^m, K_{(dd)\max}^m$.

$t_{\max\left(t_m\right)}$ – exponentially distributed random value with the mean of $t_m$.

2. Experimental part

Experiment 1: let us consider the effect of the presented level distribution of the information over the levels on the value of dynamic criterion efficiency. To do so we examine three variants:
1. Let us specify the amount of information just the same at all of the levels $O_i = 1/15 \approx 0.067$.

2. Next, we specify inhomogeneous distribution of the information amount when $O_i = 0.86$, $O_{2-15} = 0.01$.

3. Then, we specify the fourth distribution of the information amount in accordance with its assumed distribution over RMPAS levels.

The aim of experiment concerning determination of the effect characterizing the distribution of the information amount over the levels of UMAIS CE on the criterion of dynamic efficiency of CII: to elucidate which of the enumerated distributions of the information over the levels of UMAIS CE, and for what values of $t_m$ is the greatest influence on $D(t_m)$. It is required in order to determine the need in the uniform distribution over the levels of UMAIS CE of the information checked-up for its integrity.

Using the program on the simulation of CII UMAIS CE handling [6] one can calculate $D(t_m)$ for the different values of $t_m$ and the fixed value of $K_{\text{max}} = 0.5$. Let parameter $t_m$ be equal to 0.1; 0.25; 0.5; 1; 2; 5; 10. Corresponding values of $D(t_m)$ we designate as $D_1(t_m)$, $D_2(t_m)$, $D_3(t_m)$. Then one can start the program and specifies initial values of parameters: $u_\text{max}$ (the number of levels) = 15 (invariable parameter); $t_m = 0.1$ (is variable parameter); $p$ (throughput of the hardware and efficiency of CII algorithms) = 1 (invariable parameter); $a$ (parameter specifying the random value $\Psi$) = 0.5 (invariable parameter); $K_{\text{max}} = 0.5$ (invariable parameter); $O_i = 0.067$ (variable parameter).

Results of experiment representing its practical significance: when performing the experiment it became clear that the distribution of the information over the levels has rather significant effect on $D(t_m)$ in case of non-uniform distribution and for the values of $t_m \leq 2$. Note that the maximal change of $D_2(t_m)$ relative to $D_1(t_m)$ is more than three hundred percents at $t_m = 0.1$. The assumed distribution of the information over the levels at $t_m \leq 1$ has less effect on the value of $D(t_m)$. In this case the maximal change of $D_3(t_m)$ relative to $D_1(t_m)$ is of more than one hundred percents at $t_m = 0.1$. Thus, the need of the uniform distribution of the information over UMAIS CE levels is only of the prompting character.

Experiment 2: let us define the effect of parameter $K_{\text{max}}$ on the value of $D(t_m)$ and then make it clear when (i.e. for what values of $t_m$) parameter $K_{\text{max}}$ has the strongest effect on $D(t_m)$. It is required for organization of the most effective handling in CII UMAIS CE. In order to obtain results we can use the above-mentioned program.

Let us specify the initial values of parameters: $u_\text{max} = 15$ (invariable parameter); $t_m = 0.1$ (variable parameter); $p = 1$ (invariable parameter); $a = 0.5$ (invariable parameter); $K_{\text{max}} = 0.1$ (variable parameter); $O_i = 0.067$ (invariable parameter).

From the table «Analytical data for the change of $K_{\text{max}}$», presented in Figure 1, it is seen that under the change of parameter $K_{\text{max}}$ by 0.1 the value of $D(t_m)$ at $t_m = 0.1$ changes by 49 % on the average. The plot depicted in Figure 2 illustrates a gradual decrease of $D(t_m)$ at the increase of $K_{\text{max}}$, that is quite foreseeable: when the amount of information intended for the immutability check-up increases the ability of access to this information is reduced.

Results of the experiment that have a practical significance are formulated as conclusions:

1) If $K_{\text{max}}$ is increased then criterion of the dynamic efficiency diminishes (an increase of sufficiency for the integrity criterion IC $D_{\text{dcr}}$ and decrease of criterion contingent profit $D_p$), since under increase of the information amount checked-up for immutability the probability of concealment of its integrity breaking is reduced while the time required for this check-up increases.
2) With an increase of $t_m$ the rate of diminishing the criterion of the dynamic efficiency ($D(t_m)$) is reduced and this fact results in a decrease of efficiency for CII handling.

3) For $t_m$ close to zero 0 and under the change of $K_{\text{max}}$ from 0.1 to 1 the efficiency of CII handling is mostly very high.

4) In case when $t_m$ values are more than 1.5, it seems reasonable to use the value of $K_{\text{max}}=1$.

| $K_{\text{max}}$ | $D(K_{\text{max}})$ | $D(K_{\text{max},1})$ | $D(K_{\text{max},1})$ | $\%$ |
|------------------|---------------------|------------------------|------------------------|------|
| 1                | 0.1000              | 0.5649                 |                        |      |
| 2                | 0.2000              | 0.2199                 | 0.2450                 | 43.705 |
| 3                | 0.3000              | 0.1814                 | 0.1385                 | 43.2948 |
| 4                | 0.4000              | 0.1031                 | 0.0783                 | 43.1643 |
| 5                | 0.5000              | 0.0403                 | 0.0028                 | 60.9117 |
| 6                | 0.6000              | 0.0214                 | 0.0163                 | 46.8843 |
| 7                | 0.7000              | 0.0113                 | 0.0101                 | 47.1662 |
| 8                | 0.8000              | 0.0045                 | 0.0038                 | 80.1770 |
| 9                | 0.9000              | 0.0033                 | 0.0022                 | 48.8889 |
| 10               | 1.0000              | 0.0012                 | 0.0011                 | 47.9261 |
| 11               |                     |                        |                        | 49.0609 |

**Figure 1.** Analytical data for the changes in $K_{\text{max}}$.

**Figure 2.** The plot of the changes for the criterion of dynamic efficiency.

Experiment 3: now we define the ways for increasing the value of criterion «Contingent profit» for CII UMAIS CE and then we elucidate how one can considerably increase the value of this criterion and, hence, the actual profit of CE while an insignificant loss of immunity takes place.

The value of criterion $D(t_{tdc})$ is regulated by parameter $K_{\text{max}}$. With the use of above-mentioned program on the simulation of the control for CII UMAIS CE let us consider a contingent profit of CE without the application of optimization procedure, i.e. for $K_{\text{max}}=1$ and with its application, i.e. for $0<K_{\text{max}}<1$ for one working day. Let us apply the following formulas:

\[
\Pi_s = D(t_{mn}) \cdot \Pi_s,
\]

\[
\Pi_d = \Pi_s \cdot N_{s},
\]

where $\Pi_s$ – is the expectation value of profit from the regular incoming order (this order can be drawn or removed);

$\Pi_s$ – is the expectation value of profit from the regular incoming order, in case of its practical ordering calculated on the basis of data on the sale for the previous periods of time;

$\Pi_{d}$ – expectation value of the profit per one working day of CE;

$N_{s}$ – expectation value of the number of incoming orders per one working day of commercial enterprise, calculated on the basis of data on the sale for the previous periods of time.
In the previous experiments in order to calculate the values of criterion of dynamic efficiency we used the relative units of measure for $m_t$, $p$, $O_i$. In order to use variation of the values of parameters specifying CII, for practical use, in particular, for increase of the conditional profit of CE we shall further apply the standard units of measurement for the enumerated parameters. For testing of our results we used database with a total memory content of 12 GBytes, where the amount of information that should be subjected to CII procedures during the ordering procedure performed by a manager is about 900 MByte. Now, let us specify the initial data for the calculations: $u_{\max} = 15$ (invariable parameter); $t_{mn} = 7.5$ minutes (invariable parameter); $p = 1$ Mbyte/sec. (invariable parameter); $a = 0.5$ (invariable parameter); $O_i = 60$ Mbyte (invariable parameter); $K_{\max} = 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 1$; $\Pi_a = 5000$ roubles (invariable parameter); $N_j = 20$ (invariable parameter). Results are presented in Figure 3.

![Figure 3](image)

**Figure 3.** The change of $\Pi_\theta$ at $0 < K_{\max} < 1$ and $t_{mn} = 7.5$ minutes.

When reducing of $K_{\max}$ an appropriate growth of conditional profit is observed. To support this growth one can also account for the mean value of the critical time $t_{mn}$. Decrease of the latter is negatively affected on the conditional profit of CE (Figure 4).

Consider the effect of parameter $a$ defining the plot of the probability density for the random value of $\Psi$ (random value with the base probability distribution) which specifies completeness of the check-up, on the conditional profit of CE. Let us specify initial data for the calculations: $t_{mn} = 7.5$ minutes (invariable parameter); $a = 0.1; 0.2; 0.3; 0.4; 0.5; 0.6; 0.7; 0.8; 0.9; 0.99; K_{\max} = 0.5$ (invariable parameter). The result is presented in Figure 5.

This result is quite predictable: the nearer to zero possible values of the random quantity $\Psi$, the less is the value of coefficient of integrity control and, hence, smaller the time required for the performance of the control procedures.

Consider the effect of the amount of information checked for integrity on the conditional profit of CE. Now specify the initial data for the calculations: $t_{mn} = 7.5$ (invariable parameter); $a = 0.5$ (invariable parameter); $K_{\max} = 0.5$ (invariable parameter); $O'_i = 60$ MByte, $O'_i / 2 \leq O_i \leq O'_i$. The result is presented in figure 6.
Figure 4. The change of $\Pi_0$ at $0 < K_{\text{max}} < 1$ and $t_{\text{mm}} = 3.75$ minutes.

Figure 5. The change of $\Pi_0$ at $0 < a < 1$.

Figure 6. The change of $\Pi_0$ at $O_t' / 2 \leq O_t \leq O_t'$.

From the plot one can see that beginning from sixty eight percent of the information amount checked for its integrity the conditional profit of CE is close to the maximal value achieved at $K_{\text{max}} = 0.5$.

Results of the experiments presenting the practical significance and formulated in the form of one of the ways for a considerable increase of conditional profit of CE while insignificant loss of immunity: we managed to decrease the amount of information checked for its integrity, by ten percent (90 Mbyte) and increase the critical time $t_{\text{mm}}$ by ten percent (45 sec). Thus, when specifying $a = 0.1$ we can get an increase of conditional profit of CE at $0 < K_{\text{max}} < 1$ within the limits of 93 to 52 thousands of roubles unlike the limits of 87 to 26 thousands of roubles.

3. Conclusion
Results of computing experiments based on the mathematical model of CII UMAIS CE, presented in the work, make it possible to determine the strategy of effective use of CII UMAIS CE and certain ways for increase of conditional profit of the commercial enterprise at the expense of the corresponding
managerial decisions on their basis and applying of certain AIS settings in accordance with the features of business processes of commercial enterprise.

The results obtained in the process of research are true not only for UMAIS CE but for various AIS RCEAP (Russian classification of economic activities and products) applied for automation of CE activity nowadays.

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