Monitoring the Financial Performance of Using Open Source Software in Government Digital Projects

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Abstract. The purpose of this study is to develop a system for monitoring the financial effectiveness of digital development programs and the introduction of the open source software in the educational environment. The main control elements in the monitoring system is a simulation system-dynamic model which allows determining based on the experiments, the key financial indicators of the development of digital projects of an IT company in dynamics. The main advantage of the first developed model, as the basic element of the monitoring system, predicting the effectiveness of the transition to new types of information products and data management, as well as the ability to track the dynamics of the enterprise in the long term with various combinations of areas of investment into open source software distribution projects, including educational information systems. The proposed model allows you to determine key indicators of the development of an IT company: the amount of income from the sale of all IT products and services, profit, accumulated capital, additional income due to the development and expansion of the scope of the open source software, evaluation of the effectiveness of the development of information systems based on them. The results of the system-dynamic simulation are the tool for determining the balance of investment funds invested into the commercial and non-profit sector of the development of digital data of an IT company. The experimental implementation of the PowerSim simulation software in a software environment allows you to evaluate the prospects and opportunities of the IT company to switch to the expanding of the range of services and produced products by using the open source software.

Keywords: Open-Source Software, Educational Programs, Non-Profit Sector Digital Projects, Monitoring System, Simulation Modeling, Modeling Methodology, System Dynamics.

1 Introduction

New technologies - the Internet of things, cloud technology, distributed ledger, machine intelligence, big data - are fundamentally changing the systems of interaction between business and the state, for which modern information ecosystems are the basis for the

emergence of entire global markets, as well as a condition for the transition from linear technological chains to multilateral partnerships and communities. In this situation, the principles of interaction between commercial and free software market participants, in addition to network resources and services of the global information space, form other principles for the formation of the result, together with new formats of digital ecosystems [1]. In ecosysrems, citizens and business cooperate with the government in multichannel mode using different mobile devices, providing the necessary convenience and speed, developing new digital competencies for citizens [2] as part of the implementation of public projects and programs that expand the opportunities for business to interact with the state [3-6].

2 Theoretical Background

The efficiency of the implementation of state digital projects depends on the choice of a way of interaction with software providers. The first option is focused on the purchase of proprietary software - tools and platforms, the right to use which is acquired by their manufacturers on a reimbursable basis. And the second option involves the use of the open source software, which in most cases is either used for free or several times cheaper than proprietary software, because the software is produced not by a specific commercial company, but by the community [7-8].

For example, for communication between the services of state digital projects, including the participation of third-party application developers, you can use the Open-API Specification, according to which the interfaces between different programs and data warehouses is built according to uniform rules. The basis of this research is the development of a cost-effective approach to the formation of regulatory and technological rules for attracting external applications created by independent software developers to government digital projects, including open source software resources, significantly expanding capabilities due to third-party certified services and applications, in addition to services provided to citizens and businesses [9].

After the development of these rules, third-party developers are able to offer the state (the "owner" of the project) on a fee basis (in the contractor's model) the development of its individual elements and / or related applications (parts of the software and hardware complex) that use open source software from created repository of program code components and their reuse in similar digital projects, which guarantees independence from developers of proprietary software, accordingly - reduction of license fees, payments for supporting software, etc.

3 Methodology and results

The paper proposes to conduct a series of simulation experiments on the basis of the system dynamics method in order to determine the development strategy of an IT company on the basis of an invariant model of using non-commercial and commercial software, as well as to predict the integrated financial result, taking into account the in-

volvement of external sources of financing for the project, expanding digital competencies of a potential target audience - users of the open source software [10]. The main modeling hypothesis is the assumption that the threat of reducing the attractiveness of the commercial IT sector (distribution and maintenance of licensed software) may be compensated (balancing communication) by investing first-party and borrowed funds into the development of digital competencies among the target audience - potential open source software users (Fig. 1).

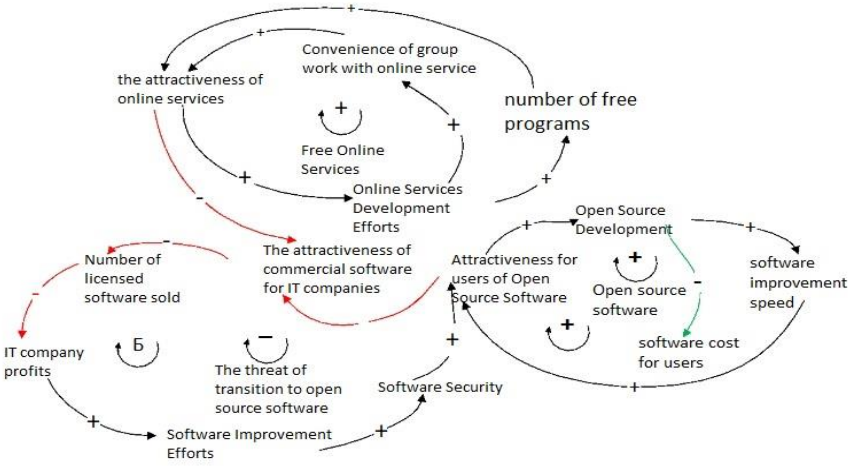

Fig. 1. Diagram of cause-effect relationships of the analysis of strategic threats to the development of the commercial sector of an IT company in the context of orientation to the development and promotion of the open source software.

The balancing feedback loop to a large extent hinders the development of the IT company, which should be supported by searching of new areas of development, making efforts to improve the software [11].

For this purpose, the model highlights positive feedback loops, Online services and Open source software (for example, Open Office from Google), and programs developed on the basis of the open code (in particular, the Linux operating system), shown in Fig. 1, as factors of external influence, the intensity of which should be timely responded to by the company.

As you know, for a business unit, the only source of capital accumulation, as well as a source of investment in development, is the resulting profit, which is the difference between the income and expenses of the enterprise. Income is the entire revenue from the sale of IT products and services, including the expected growth of the open source software and integrated IT solutions (which, in turn, are the combination of IT products and IT services).

To determine the balance of investment funds invested into the commercial and non-profit sector of the IT company, we turn to the formalization of the main parameters of a dynamic simulation model [12, 14]. For the main processes of the company in terms of developing only the commercial sector (commercial software), the main indicators

in dynamics are presented in the form of difference equations, for the main storage level - the capital of the enterprise:

$$NK(t) = NK(t-1) + D(t) - Z(t), \quad (1)$$

where NK (t) is the amount of capital of the IT company accumulated for previous periods at the time t;

NK (t-1) - the amount of capital accumulated for previous periods at the time (t-1);

D (t) - total income from the sale of IT products and IT services in the reporting period t;

Z (t) - costs of the enterprise in the reporting period t.

The total costs of IT companies are calculated by the formula:

$$Z(t) = AZ(t) + ZS(t) + PZ(t) + OT(t) + I(t), \quad (2)$$

where AZ (t) - administrative costs;

ZS (t) - certification costs;

PZ (t) - variable costs in the reporting period (includes the cost of purchasing software and hardware with their subsequent implementation both individually and as part of complex IT solutions, as well as the cost of providing IT services);

OT (t) is the general wage fund;

I (t) - the volume of investments in the development of the enterprise in the reporting period.

Administrative costs are conditionally constant. The proportion of variable costs (except for labor remuneration) for the provision of IT services is usually 12% -18% (average 15%) of the cost of selling the service. The average affiliate discount on IT products is provided to the company in the amount of 20%:

$$P_z = 0{,}8 \cdot P_r, \quad (3)$$

where Pz is the purchase price of the IT product from the manufacturer;

Pr is the selling price of the IT product to the client.

Thus, variable costs (costs for the purchase of IT products for the purpose of their subsequent sale, as well as for the provision of IT services) are calculated by the formula:

$$PZ(t) = 0{,}8 \cdot d_p \cdot D(t) + 0{,}15 \cdot d_y \cdot D(t), \quad (4)$$

where PZ (t) - variable costs in the reporting period;

dy - the share of IT services in sales revenue;

dp - the share of IT products in sales revenue (dp = 1– dy).

Analysis of sales of the studied IT companies shows that the share of IT services in revenue from sales is about 40%, and the share of IT products is about 60%. A mixed wage system is also taken into account: a fixed minimum wage combined with a premium, the amount of which, as a rule, is set as a percentage of the cost of IT products

and services sold. So that, the size of the wage fund in the proposed simulation model is calculated by the formula:

$$OT(t) = OT_{fix} + pr_p \cdot d_p \cdot D(t) + pr_y \cdot d_y \cdot D(t), \quad (5)$$

where OT (t) is the total size of the wage fund;

OTfix - a fixed part of the payroll fund;

prp - premium for the implementation of IT products;

pry - premium for the implementation of IT services.

The balance of interests in the company, as well as financial resources allocated for the development and distribution of the open source software for the purpose of reducing possible losses from sales of commercial software is achieved by the sequence of the following measures: formation of the target audience - potential users of the open source software; selection and training of technical personnel and teachers; knowledge management of the target audience; expanding industry presence, including into the online environment; updating the material and technical base, project infrastructure; management of security and safety of information systems.

These key directions of development projects for the transition to open source software form the basis of a system of monitoring the effectiveness of these programs in an IT company, and in the simulation they are represented by a system of switches and tuning coefficients of the model for analyzing the sensitivity of the IT company's accumulated capital to ongoing changes:

$$I(t) = \sum_{i=1}^{6} M_i(t), \quad (6)$$

where Mi (t) is the cost of events in the i-th direction of the open source software development project, i = 1 ... 6.

The main assumptions adopted for experimental modeling are listed below. Investments in the development of IT-business enterprises are made during the first year. In all areas of the open source software development project, except for the third, the amount of investment into the development is assimilated evenly throughout the year.

In the direction of "Target audience knowledge management", it is planned to hold three thematic seminars on information technologies throughout the year (the costs of staff training in the relevant reporting periods have been taken into account), as well as funding for advertising events (a fixed amount monthly).

The effectiveness of investment into the events, as stages of the open source software development project in each of the areas of development of an IT company, is determined by the ratio of the expected effect (increase in the monthly open source software implementation) to the amount of investments in the project areas.

The income from the sale of the open source software and related information services consists of two components:

$$D(t) = SD(t) + DD(t), \quad (7)$$

where SD (t) is the income from the sale of all IT products and services in the reporting period t (calculated based on the analysis of data from previous periods).

DD (t) - additional income from software products and services implemented in the reporting period t open source by increasing the speed of improving the open source software.

A graphical interpretation of the simulation results is presented in Fig. 2. The proposed model allows us to determine key indicators of the development of an IT company (the amount of income from the sale of all IT products and services, profit, accumulated capital, additional income due to the development and expansion of the scope of the open source software), to predict the dynamics of the company's development for the nearest and long term.

Fig. 2. Dynamics of key development indicators of the open source software in an IT company based on the results of simulation experiments.

According to the results of simulation experiments, subject to investment, the amount of accumulated capital is approximately doubled, which confirms the usefulness of the proposed measures for the development of the open source software.

The advantage of the developed system dynamics model is the possibility of choosing the directions of development of the open source software development project and their possible combinations, as well as tracking changes in the resulting indicators (income, accumulated capital, profit), which allows you to choose the most suitable open source software development option for a particular enterprise [13].

In the table 1, there are the forecast values of indicators of monitoring the open source software system development efficiency (profit, return on investment), as well

as an indicator of development potential, as a relative increase in average monthly profit.

The simulation results show that option 5 (the implementation of all the proposed measures) is the most effective, bringing 181.1% profit growth. Taking into account the limited investment resources at the enterprise, option 2 may be implemented (expanding the scope of the open source software combined with staff training and expanding the presence in the online environment), which is characterized by the growth rate of 45.5%.

Table 1. Financial indicators for assessing the development potential of an IT company with various options for implementing measures to develop open source software.

Open source software development project activities	Possible combinations of the sequence of stages of a development project open source software					
	Basic option (without investment)	Option 1	Option 2	Option 3	Option 4	Option 5
The amount of investment, thousand rubles	0	162 000	207 000	151 000	322 000	583 000
Average monthly earnings, thousand rubles	17 280	21 431	25 139	19 887	45 076	48 578
Payback period, months	-	39.0	26.3	57.9	11.6	18.6
Profit growth (indicator of development potential), %	-	24.0%	45.5%	15.1%	160.9%	181.1%

4 Conclusion

Based on the results of the consideration of the existing approaches to assessing the conditions of the development of an IT company taking into account a strategic alternative - expanding the scope of the open source software (as a threat from a decrease in the attractiveness of the commercial sector of an IT company) and identifying conditions for compensating for losses by investing own or borrowed funds in the development of digital competencies of the target audience - potential users of the open

source software. The authors proposed a simulation model that allows determining the key financial benefits during the experiments, indicators of the development of IT companies in dynamics.

The undeniable advantage of the author's model of system dynamics is the multivariate use - both for the current assessment and for monitoring the dynamics of the development of the enterprise in the long term with various combinations of areas of investment in open source software distribution projects (the possibility of varying parameters).

References

1. Dolganov, A.N., Ford, V., Tarasyev, A.M., & Turygina, V.F.: Optimization of Information Resources in Industrial Ecology. IFAC-PapersOnLine 51(32), 67-72 (2018).
2. M. Medvedeva, V. Kalinin, D. Berg, M. Medvedev: Formation of Elite Specialists in Geosciences: Proposals for General Strategy. In: 15th International Multidisciplinary Scientific Geoconference SGEM 2015, Conference Proceedings, vol. III, pp. 887-893 (2015).
3. Agbozo, E., and Spassov, K.: Establishing efficient governance through data-driven e-government. In: Proceedings of the 11th International Conference on Theory and Practice of Electronic Governance, ICEGOV 2018, pp. 662-664, Association for Computing Machinery (ACM) (2018).
4. Agbozo, E.: Developing a digital government framework for Sub-Saharan Africa. In: Proceedings of 17th European Conference on Digital Government, ECDG 2017, vol. F129463, pp. 294-305 (2017).
5. Agbozo, E.: The private sector as an e-government enabler. In: B S. BenDhaou, L. Carter, and M. Gregory (eds.), ACM International Conference Proceeding Series vol. F148155, pp. 508-509 (2019).
6. M.A. Medvedeva and E. I. Komotskiy: About usage of data mining methods for fraud detection in the sphere of communal services. AIP Conf. Proc. 1738, 110011 (2016).
7. Lisa R. Wolfisch, Rachael LaPorte Taylor: Open Source at the Census Bureau and FedStats. In: Proceedings of Conference Open Source: A Case for e-government, Washington, USA (2002).
8. Thomas Bushnell: Session at UDS by Google developer «How Google Developers Use Ubuntu». Ubuntu Vibes (2012).
9. D.B. Berg, K.A. Beklemishev, A.N. Medvedev, M.A. Medvedeva: Modeling of the competition life cycle using the software complex of cellular automata PyCAlab. AIP Conference Proceedings 1690, 030003 (2015).
10. D.A. Novikov: Theory of Control in Organizations. Nova Science Publishers, N.-Y. (2013).
11. Katalevskij, D.Y.: Upravlenie rostom organizacii na osnove sistemno-dinamicheskogo podhoda. Vestnik Moskovskogo universiteta, ser. 21 Upravlenie (gosudarstvo i obshchestvo), vol. 4. (2007) (in Russian).
12. Forrester, J.W.: Counterintuitive behavior of social systems. Technology Review, 73(3), 52-62 (1971).
13. G.K. Shevchuk, D.B. Berg, O.M. Zvereva, M.A. Medvedeva: Mitigation of Short-term Disturbance Negative Impacts in the Agent-Based Model of a Production Companies Network. AIP Conf. Proc. 1906, 070014 (2017).

14. Ilysheva, N.N., Lapshina, S.N., Detkov, A.A., and Rylova, A.P.: Analysis and modeling of dynamic changes in the Russian economy macroeconomic indices (2002 - 2016). AIP Conf. Proc. 1978, 440015 (2018).