Time Multipliers in Project Effectiveness Models for Ensuring the Survivability of Information Systems*

Yuriy Syvytsky[1,†] and Viktor Shevchenko[1,*,†]

[1] *Institute of Software Systems of the National Academy of Sciences of Ukraine, 40/5 Akademik Hlushkov ave., 03187 Kyiv, Ukraine*

Abstract

The paper is devoted to the topical issue of the development of methods for modeling the effectiveness of projects to ensure the survivability of information systems. An analysis of existing research on the topic of the paper revealed a contradiction between the need for practice in the relevant modeling methods and the lack of appropriate theoretical and applied approaches. The purpose of the study is to develop methods for modeling the development of projects to ensure the survivability of information systems, in particular, taking into account the possibilities of additional financing of technologies for accelerating project implementation. The basic models of project and technology development were analyzed: models of exponential infinite growth, linear growth, and exponential entry into the saturation zone. A generalization of the basic models in a single logistic dependence was proposed. The logistic dependence was determined to be the most universal and adequate for modeling the processes of project and technology development. A classification of logistic development dependencies was performed: EGEL/BiS, EL/BiS, EL/BLO, EL/BiF, and their main properties were analyzed. For each type of dependency, a model was built for different parameter values corresponding to different scales of projects to ensure the survivability of information systems. An approach was proposed to implement the “Time is Money” principle, namely, a procedure was proposed for converting additional funding into acceleration of project implementation deadlines. For this purpose, a time multiplier value was proposed, which is a function of the amount of additional funding, has a logistic nature, and determines the patterns of the project implementation acceleration indicator depending on the amount of additional funding. Simulation was performed for a progressive time multiplier, which leads to acceleration of project implementation, and simulation was performed for a regressive time multiplier, which leads to inhibition of project implementation. It was found that the use of a time multiplier does not change the qualitative nature of project development dependencies.

Keywords

computer simulation model, information system, survivability, logistic dependence, useful effect, resource, management decision support, automation, optimization

1. Introduction

It is not enough to simply create an information system. It is also necessary to ensure its stable functioning in conditions of malicious and unintentional harmful influences. The issue of ensuring the survivability of information systems has become especially relevant in conditions of war. Relevant projects are aimed at ensuring the survivability of information systems, which have their life cycle and the dependence of the useful effect on input resources. Financial, material, human resources, intangible assets, and time resources can be considered as input resources [1]. For simplification, the required number of resources is usually planned for the project stages. It is then assumed that each stage is provided at a sufficient level and further control of the project’s success is carried out using the dependencies of the project’s useful effect on time. Verifying the correctness of management decisions by implementing them in real projects carries the risk of unexpected consequences and can lead to large economic losses. It is safer and more economically

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* Corresponding author.
† These authors contributed equally.
ys@intecracy.com (Y. Syvytsky); gii2014@ukr.net (V. Shevchenko)
0009-0008-9947-6653 (Y. Syvytsky); 0000-0002-9457-7454 (V. Shevchenko)

feasible to use modeling. Models are used for a deeper study of the patterns of development of specific types of projects and for predicting the possible consequences of various options for alternative management decisions to find optimal project management. Of particular interest is the search for ways to accelerate project implementation and predict the dynamics of development for such situations.

Thus, the development of methods for building models of project effectiveness to ensure the survivability of information systems is a relevant task. Also relevant is the issue of modifying existing development models to take into account the possibilities of accelerating project implementation. For this purpose, in this work, time multipliers were introduced into the model, which takes into account the impact of additional funding on the possibilities of accelerating project implementation.

2. Analysis of existing studies

Survivability is the ability to realize the goal of functioning under adverse influences [2]. Survivability should be ensured by comprehensive actions to ensure certain properties of information systems, properties of projects for the creation of such systems, a set of organizational measures, appropriate process management, high-quality planning, and forecasting of possible consequences of management decisions.

A large number of applied methods for ensuring the survivability of information systems are built based on numerical assessment and analysis of information security risks [3–6]. Unfortunately, these approaches do not use the potential of forecasting methods based on modeling dynamic processes of project development.

Forecasting the consequences of management decisions to counter cyberattacks of an epidemiological nature was implemented in work [7] based on the use of dynamic models of epidemic development. Unfortunately, the dynamics of the development of relevant projects to counter threats to the survivability of information systems were not considered.

Models for ensuring the survivability (guaranteeability) of information systems (in particular, situational centers) of critical infrastructure facilities were considered in the works [8, 9]. The value of recent works lies in the creation of models for the development of information systems. Unfortunately, the issues of the dynamics of the development of survivability projects were not considered. Also, insufficient attention was paid to the issues of taking into account financial resources.

The issues of optimizing the financing of projects for the creation of information protection systems are considered in [10]. However, the issues of financing technologies for accelerating project implementation are not considered.

Methodological approaches at the level of generalization of best-world practices are considered in [11, 12]. Unfortunately, these works do not use the tools of dynamic models that would allow predicting the consequences of management decisions and finding optimal solutions for managing projects to ensure the survivability of information systems.

When analyzing existing research, a contradiction was identified between the need for practice in methods for modeling the effectiveness of projects to ensure the survivability of information systems and the lack of appropriate theoretical and applied approaches.

Purpose of the paper: development of methods for modeling the development of projects to ensure the survivability of information systems, in particular, taking into account the possibilities of accelerating project implementation through additional financing of project implementation acceleration technologies.

3. Classification of logistic models of effectiveness of projects ensuring the survivability of information systems

Previously, the authors used an atomic development model, which can also be applied to the analysis of the useful effect of projects to ensure the survivability of information systems (Fig. 1). Such a model is sometimes called the “black box” model. This means that during the analysis it is important to focus on the input resources, the output useful effects, and the functional dependence *f(x),* which is hidden in the “black box”.

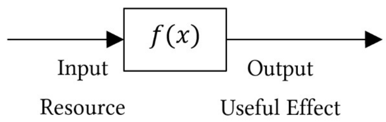

Figure 1: Atomic model of development of organizations, technologies, and information systems

The most common “black box” models are exponential infinite growth models.

$$E=d+(a-d)e^{\frac{1}{T}(t-s)}, \tag{1}$$

linear growth

$$E=d+\frac{(a-d)}{T}(t-s), \tag{2}$$

exponential entry into the saturation zone

$$E=d+(a-d)\left(1-e^{\frac{-1}{T}(t-s)}\right). \tag{3}$$

Or you can use a logistic growth model, which combines all three of the above models (Fig. 2).

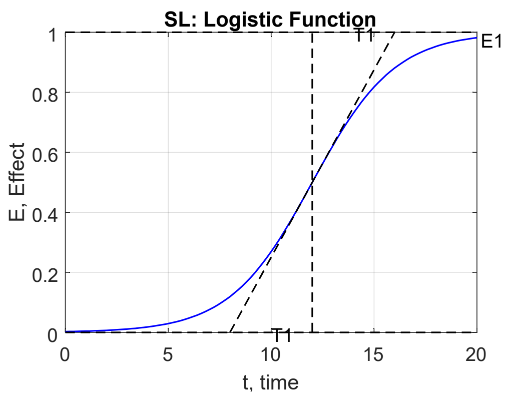

Figure 2: Logistic dependence of the beneficial effect of the project over time

It is easy to see that the lower part of the logistic model is similar to the exponential model of infinite growth, the middle part is similar to the linear growth model, and the upper part is similar to the exponential model in the saturation zone. The logistic dependence in integral form has the form

$$E=SL(t)=d+\frac{a-d}{1+e^{\frac{-2}{T}(t-s)}}. \tag{4}$$

Here d and a are the ordinates of the lower and upper asymptotes, respectively, s is the abscissa of the point of central symmetry of the logistic dependence, T is the constant value of the logistic dependence. In its meaning, the constant value of the logistic dependence is similar to the constant value of the exponent but differs from the latter in scale by a factor of 2.

The graph (Fig. 2) clearly shows the lower and upper asymptotes and two segments on these asymptotes are marked, corresponding to the constant values of the logistic dependence $T1$, which together with the ordinates of the asymptotes determine the growth rate of the development process of the project to ensure the survivability of the information system.

The main assumption of the study is that we are investigating projects that, within the framework of the selected technologies to ensure the survivability of information systems, have an upper limit of development. That is, after a certain period, the development process approaches the upper asymptote and cannot exceed it. To be precise, it cannot touch the asymptote, but can only infinitely approach it. This corresponds to the real situation of project development. To rise above the current asymptote, it is necessary to introduce new technologies that simply have a different upper asymptote, which is located higher. However, this can lead to certain development delays at the initial stages of project implementation.

The figure (Fig. 3) shows the logistic dependences of the growth of the effect of projects that use different information technologies, which provide different levels of the maximum useful effect (upper asymptote). The distinctive features of these dependencies are that they contain both a section similar to an exponential in the zone of infinite growth and a section similar to an exponential in the zone of approaching the limit. We will classify such forms of logistic dependences as EGEL (Exponential Growth + Exponent with a Limit).

In terms of physical content, the ordinate of the dependence corresponds to the indicators of the success of the project. This can be income, profit, the amount of damage that was avoided, the quality of protection, the level of survivability, the percentage of guaranteed operability of the information system, the speed of the system, etc.

A feature of the technologies presented in (Fig. 3) is that they have a stage of almost zero development at the beginning of implementation and, in addition, periods of rapid growth that begin at noticeably different points in time. That is, these projects have fundamentally different durations of the initial stages of implementation.

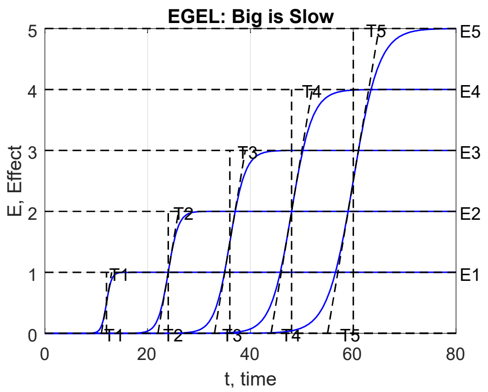

Figure 3: Logistic dependence of the useful effect of the project depending on time. Projects with a small difference in the maximum level of development $a = [1\,2\,3\,4\,5]$

It is logical that the higher the potential of the maximum level of useful effect of a technology, the more time such a technology requires for implementation. We will denote the type of such projects as BiS (Bigger is Slower). Although in some cases, even for projects with different values of the upper limit of technology development (upper asymptote), the implementation time does not differ significantly (Fig. 4), but it still corresponds to the BiS type.

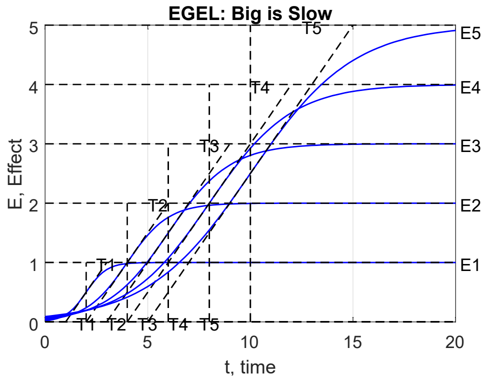

Figure 4: Logistic dependence of the useful effect of the project over time. Projects with a small difference in the maximum level of development $a=[1\,2\,3\,4\,5]$ and with a small difference in the beginning of growth (symmetry point $s=[2\,4\,6\,8\,10]$)

To diversify the computational experiment conditions, one study also considered projects that had a large difference in the maximum level of development of the technology they used (Fig. 5).

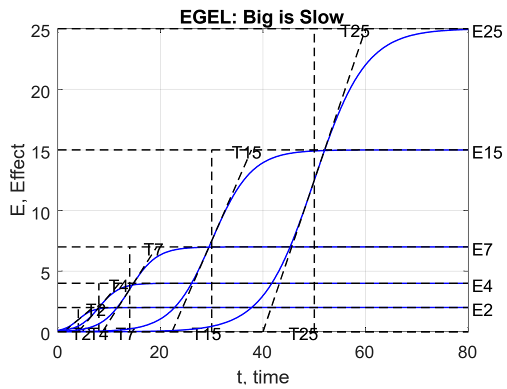

Figure 5: Logistic dependence of the useful effect of the project depending on time. Projects with a large difference in the maximum level of development $a=[2\,4\,7\,15\,25]$

The logistic dependencies discussed above are inherent in almost all technologies that start from zero or almost from zero. They are characterized by the presence of a stage of almost zero growth at the beginning of the technology implementation and all of them are EGEL/BiS projects.

At the same time, some technologies practically do not lose time for implementation and immediately begin to produce a useful effect that is proportional to the time spent (Fig. 6).

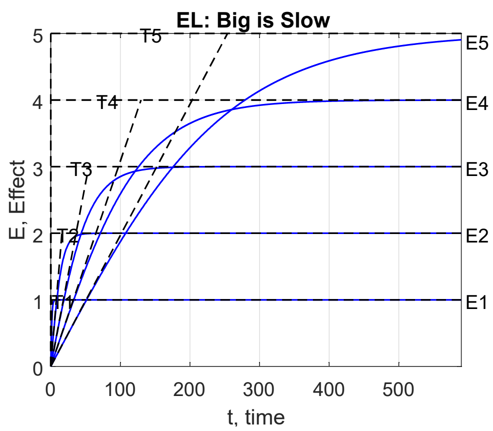

Figure 6: EL—dependence of the useful effect of BiS—project on time. Projects with a small difference in the maximum level of development $a=[1\,2\,3\,4\,5]$

Over time, such technologies also reach the limits of their capabilities and slow down their development. Visually, such dependencies are similar to the dependencies of exponential development in the saturation zone. Therefore, we will further classify them as EL dependencies (Exponential function with Limit). In addition to BiS projects, there are also BLO projects (Bigger have Bigger Limit Only), which grow from the same trunk and differ only in the level of the upper asymptote (Fig. 7).

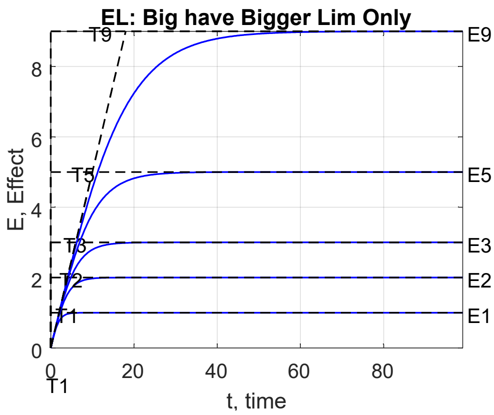

Figure 7: EL—dependence of the useful effect of the BLO—project on time, $a = [1 2 3 5 9]$

It is also worth highlighting BiF projects (Bigger is Faster), in which large projects grow faster than small ones. We consider such types of projects rather for the sake of completeness of the classification. Because they are either very rare or completely unrealistic (Fig. 8).

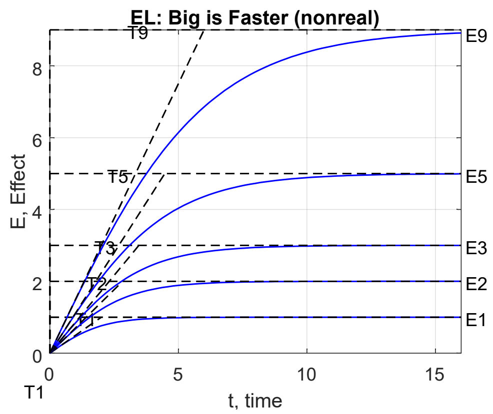

Figure 8: EL—dependence of the useful effect of the BiF project on time, $a = [1 2 3 5 9]$

Thus, the classification of projects that we analyzed includes the following types of projects: EGEL/BiS, EL/BiS, EL/BLO, and EL/BiF.

4. Modification of models taking into account the principle of "Time is Money"

The dynamics of the growth of the useful effect of projects over time was considered under the conditions of normal resource provision of projects. Any material resource at the input of the project can be estimated in terms of money. Any resource is converted into an output useful effect according to the logistic dependence on the entire life cycle of the project or at its stages. Regarding the time resource, the issue is not so obvious. The study determined that it is difficult to establish a direct time-money relationship. However, money can be used as an input resource in technologies aimed at accelerating technological processes. Let us introduce the concept of a "time multiplier," as a multiplier that shows the degree of acceleration of technological processes with the help of additional financing.

We consider projects that have normal (normative or planned) resource provision. Therefore, with zero funding for time acceleration technologies (time multipliers), the project will develop in the usual way. With additional funding for time multiplier technologies, all basic project operations will be performed faster. In practice, this can be achieved by introducing additional personnel who will work in the second or third shift, by purchasing more powerful computing resources that allow faster and more efficient solutions to the issue of ensuring the survivability of information systems, or by purchasing more effective software, or by purchasing analytical information from other companies regarding possible malicious actions by potential information security violators, etc. At the same time, time multiplier technologies, like other technologies, have their upper limit on the acceleration of basic project processes. On the other hand, time multiplier technologies do not turn on instantly. There is a certain level of initial financing of these technologies, which gives a zero increase in the value of the time multiplier. That is, the dependence of the time multiplier on the input financing is also logistic. The only fundamental difference from the dependencies that we considered above is that at the zero moment, the value of the multiplier is always equal to 1 (Figure 9). To ensure this condition, it is necessary to solve the following equation for the ordinate of the lower asymptote

$$1 = SL(t) = d + \frac{a-d}{1+e^{\frac{-2}{T}(t-s)}}. \tag{5}$$

After transformations we get

$$d = 1 + (1-a)e^{\frac{2}{T}(t-s)}. \tag{6}$$

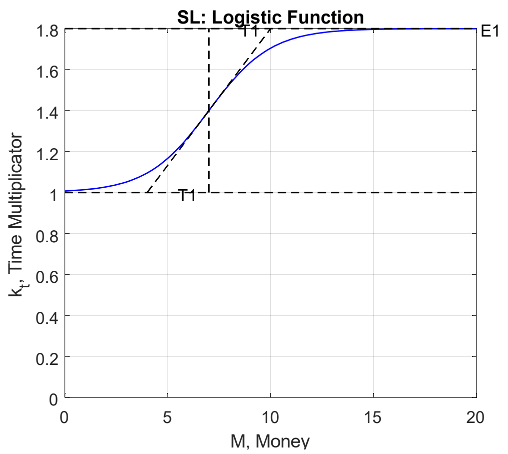

Figure 9: Dependence of the progressive time multiplier on the amount of financing

Further interaction between the material resources of the time multiplier and time resources can be described by the following dependence

$$E = SL_E(t\, SL_t(k_t t)). \tag{7}$$

Here M is the money entering the time multiplier technology, $SL_t(k_t t)$ is the dependence of the time multiplier value on the amount of money entering its input, k_t is the specific value of financing per unit of time, t is time, SL_E is the logistic dependence of the useful effect of the technology of ensuring the survivability of the information system depending on the time of implementation of the corresponding project. In this case, the linear dependence of the time-based financing increase of the time multiplier is considered.

5. Progressive Time Multiplier

The time multiplier that accelerates the implementation of the project (Figure 9) will be called progressive. The results of modeling the impact of the progressive time multiplier technology on the basic projects EGEL/BiS, EL/BiS, and EL/BLO, which we analyzed above, are presented in (Figs. 10–13). The modeling results show that the use of the progressive time multiplier accelerated the implementation of projects. But at the same time, it did not change the qualitative picture of the dependence of the useful effect on time for all types of projects.

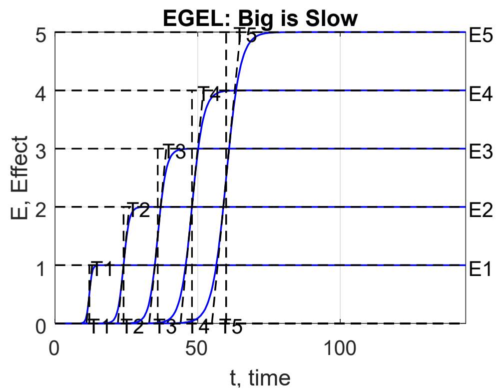

Figure 10: Dynamics of growth of beneficial effects of EGEL/BiS type projects under conditions of operation of progressive time multiplier technology, $a=[1\,2\,3\,4\,5]$

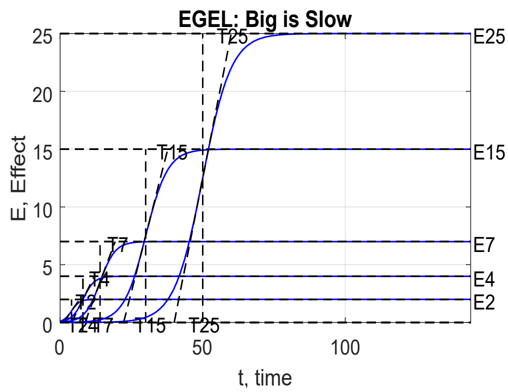

Figure 11: Dynamics of growth of beneficial effects of EGEL/BiS type projects under conditions of operation of progressive time multiplier technology, $a=[2\,4\,7\,15\,25]$

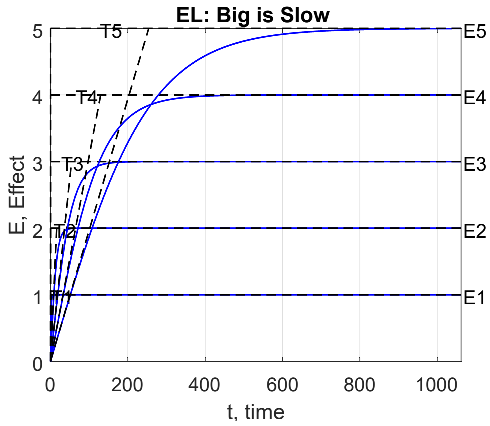

Figure 12: Dynamics of growth of beneficial effects of EL/BiS type projects under conditions of operation of progressive time multiplier technology, $a=[1\,2\,3\,4\,5]$

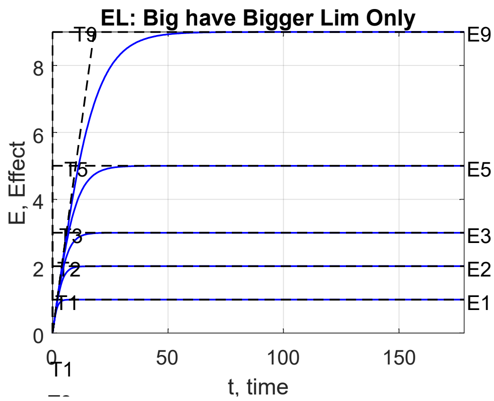

Figure 13: Dynamics of growth of beneficial effects of EL/BiS type projects under conditions of operation of progressive time multiplier technology, $a=[1\,2\,3\,5\,9]$

6. Regressive time multiplier

In addition to the progressive time multiplier, there may also be a regressive time multiplier, which slows down the project implementation (Fig. 14). The regressive time multiplier may appear as a result of the action of unfavorable factors in the development of the project. Its introduction is necessary for the systematic consideration of possible project development options. The regressive time multiplier model is represented by a logistic dependence that decreases with time. The multiplier begins its movement from the asymptote d, which we previously called the lower asymptote, and decreases its value to the asymptote a, which we previously called the upper asymptote. That is

$$d>a \tag{8}$$

In this case, it would be more correct to call d the ordinate of the asymptote of the beginning of the movement, and the value of a the ordinate of the asymptote of the end of the movement. The results of modeling the impact of the regressive time multiplier technology on the basic projects EGEL/BiS, EL/BiS, and EL/BLO are presented in (Figs. 15–18).

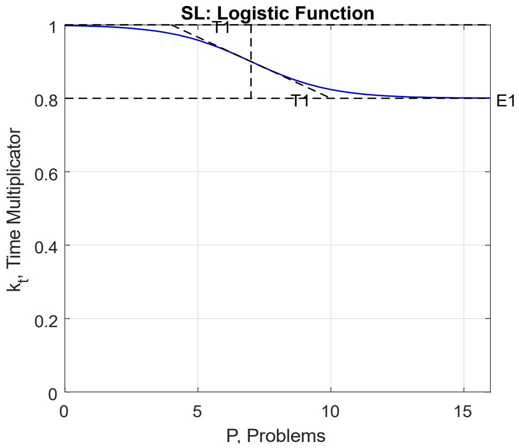

Figure 14: Dependence of the regressive time multiplier on the amount of financing

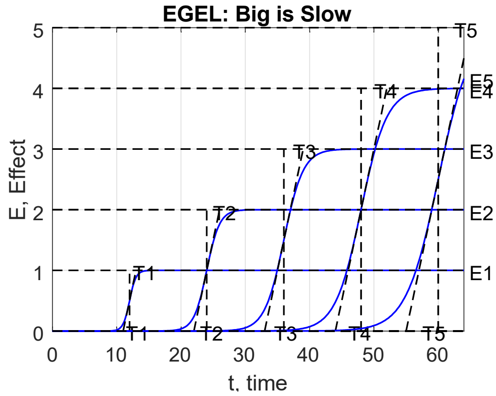

Figure 15: Dynamics of growth of beneficial effects of EGEL/BiS type projects under the conditions of operation of the regressive time multiplier technology, $a=[1\,2\,3\,4\,5]$

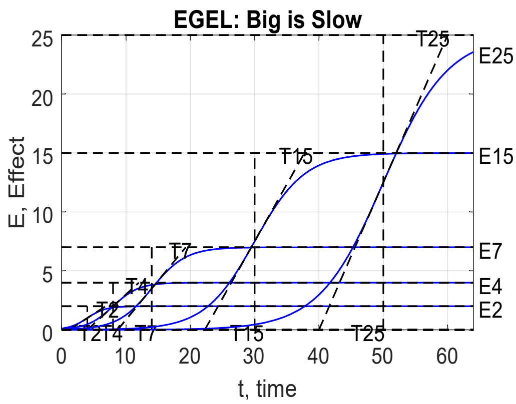

Figure 16: Dynamics of growth of beneficial effects of EGEL/BiS type projects under the conditions of operation of the regressive time multiplier technology, $a=[2\,4\,7\,15\,25]$

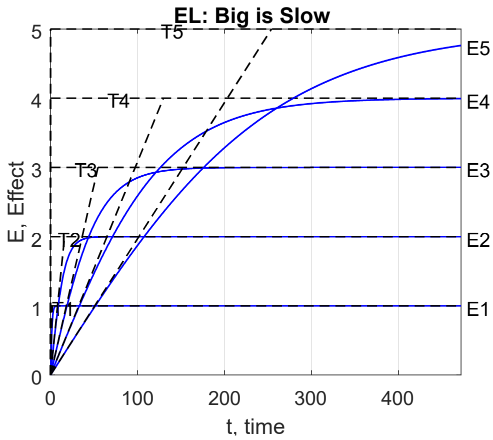

Figure 17: Dynamics of growth of beneficial effects of EL/BiS type projects under the conditions of operation of the regressive time multiplier technology, $a=[1\,2\,3\,4\,5]$

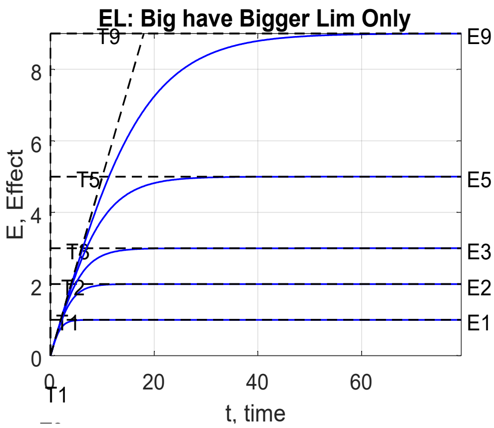

Figure 18: Dynamics of growth of beneficial effects of EL/BiS type projects under the conditions of operation of the regressive time multiplier technology, $a=[1\,2\,3\,5\,9]$

The modeling results show that the use of the regressive time multiplier slows down the implementation of projects. But at the same time, just as in the case of the progressive multiplier, it does not change the qualitative picture of the dependence of the useful effect on time for all types of projects.

Conclusions

The paper proposes a classification of project development patterns: EGEL/BiS, EL/BiS, EL/BLO, EL/BiF. This classification can be applied to projects to ensure the survivability of information systems. The models are modified taking into account the “Time is Money” principle. For this purpose, the “time multiplier” indicator is proposed, which allows linking financial resources with indicators of project implementation acceleration. The models are modified taking into account time multipliers. The modeling results for the progressive time multiplier and for the regressive time multiplier are obtained. The analysis of the modeling results showed that the use of time multipliers changes the time frames of projects, but does not affect the qualitative picture of the patterns of project development.

Declaration on Generative AI

While preparing this work, the authors used the AI programs Grammarly Pro to correct text grammar and Strike Plagiarism to search for possible plagiarism. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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