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Simulation and Optimisation of Business Process Management: Case Study of IT Company

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Abstract

Background: In managing business processes of complex hierarchical systems, primary attention is given to analysing, accelerating, and optimising the basic processes typical for any company. **Objectives:** The goal of this work is to prove that while managing business processes, it is crucial to consider the peculiarities of the external and internal environment to determine the effects of individual triggers. **Method:** An example of business process analysis was provided regarding the peculiarities of managing IT service companies operating in a dynamic environment of rapid technological changes. The business processes analysis of IT service companies in Ukraine was conducted. Business process groups characterised by low use of labour and financial resources and excessive and high levels of risk management were determined. **Results:** An algorithm for optimising the IT company's business processes was developed. Simulation and optimisation models for managing IT company business processes were developed using scenario modelling and simulation techniques. **Conclusion:** Based on these models, a predictive evaluation of management impacts on business processes was conducted, representing individual clusters according to defined management strategies.

Keywords: business process; cluster; management simulation model; business process activities

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Introduction

The article studies the peculiarities of modern concepts and ideas regarding managing the development of complex systems. These represent a complete object consisting of functionally diverse but connected by functional subordination to achieve the set goals. Similar management objectives are widespread at this stage of the development of economic systems. These can be corporations, multidisciplinary enterprises, and even organisations that provide regional interaction within one country.

The needs of the modern dynamic market require reviewing the life cycle of products and services while maintaining the quality of the final product (Stark, 2022). That causes a contradiction in the management of the company's development because it forces the companies to make radical changes to the strategic development plans of enterprises (Kopei et al., 2023). The management concept relies on the company management paradigm as a framework, which can be adapted, in this case, to meet the specific needs of project management in response to changing circumstances (Soleymani, 2020). Nevertheless, the newer information, knowledge and skills become available to the enterprise, the more demands society has for the final product, and vice versa. Such a situation begins to make adjustments to management processes, and an unchanged management paradigm, i.e., the use of old methods and models in new fast-moving conditions, can lead not only to a significant lag in competition but also to the complete collapse of the business.

Most modern organisations are hierarchical systems operating in conditions where information is the central resource, and the economy has a network structure. The organisation's external environment acts as a broadcaster of information that has a targeted impact on forming the final product. It orients the organisation to change or improve its management structure into a group of interconnected blocks that aim to implement a single strategy in modern informatisation conditions (Webler, 2022). On the one hand, such “blocks” are easier to manage and have sufficient flexibility. On the other hand, this causes additional informational noise, which can hinder the timely detection of any problematic moment. At the same time, flexibility advantages can become an obstacle in coordinating resources, but they allow single-out individual management processes and exert a targeted influence on them.

The abovementioned is especially typical for companies working in the field of information technologies (IT). The IT industry generally finds it difficult to harmonise with the classical management paradigm based on the rational production organisation to obtain the maximum additional value. The “maintenance-development” cycle does not coincide with the life cycle of IT companies' products and services since they are oriented to the “innovation-development” cycle. In this case, the “maintenance” step is replaced by an innovative step, which does not simply save the work result but updates it and brings it to the level of obtaining a new version or a significantly new product according to the efficiency criterion (Guo et al., 2020). Each step is a separate business process (BP) (Mahdiraji et al., 2020) because the product is being refined and value is added.

An essential ability of modern organisations is a flexible and effective response to unexpected events (Röglinger et al., 2022). Critical events can be caused by a lack of resources, including financial (Goel et al., 2021) or human (Lee et al., 2019), which in turn can be caused by an incorrect distribution or sales management approach (Kajba et al., 2022). Researching this aspect in the example of IT companies in China (Ilmudeen, 2022) revealed a positive and significant relationship between marketing turbulence, flexibility and innovation potential. Technology innovations can soften the impact of marketing turbulence by changing how companies’ function. This shift often requires companies to focus on product promotion and sales to drive innovation.

The above can be studied as an example of a modern direction in IT service companies as blockchain platforms. For example, the Ethereum and Caterpillar platforms allow individuals to handle their business processes independently without relying on a central authority for transactions. Such functions are basic blocks for performing joint business processes between the parties. A blend of trusted Business Process Management Systems (BPMS) that rely on the widely used Business Process Model and Notation (BPMN) standard is utilised to minimise errors, which in turn increase organisational performance (Suša Vugec et al., 2020; Slavec et al., 2023; Dwivedi et al., 2021). This approach enables the creation of convenient abstractions, which, in turn, facilitates the quick development of process-oriented software programs (López-Pintado et al., 2019). Something similar applies to the management processes regarding the Internet of Things (IoT). The IoT-based business model improves overall capabilities but has several challenges regarding the accuracy of business asset information and difficulty in requirements analysis. All this leads to the need to manage a large volume of data. It is common practice to break down extensive processes into smaller sub-processes to increase efficiency and prioritise the most critical aspects of a business. This helps to minimise any potential issues that may arise (Shoukry et al., 2021).

The study aims to present the methodological foundations of creating a paradigm for managing the development of an organisation as a complex hierarchical system operating in a rapidly changing external environment.

Throughout the study, we examine the peculiarities of structural changes in business process management as they undergo optimisation. The given optimisation model allows considering a separate BP through subsidiary processes. On this basis, a simulation modelling method is proposed, which allows considering the future consequences of decision-making at the current moment within the limits of business processes at all levels. The article reveals the necessity of studying the complex properties and business process optimisation of a complex hierarchical system through their detailing. This enables the identification of the optimisation model's variables and their use as controlling influences in managing individual triggers.

The article is structured in the following way. Section 2 provides the aim formalisation, criteria and limitations in managing a complex system, which allows the writing down the structure of each BP according to the function of efficiency and details of business processes in a complex hierarchical system concerning IT service companies, as the object of research. Section 3 presents the simulation results with the development of optimisation model flow charts. Section 4 describes the obtained results and measures that can be offered to companies with a complex hierarchical management system to optimise individual BPs. Section 5 presents the conclusions of the work.

Methods

Formalisation of the aim, criteria, and limitations

A system is a set of means that create a specific structure to achieve a particular goal efficiently. By formalising a complex hierarchical system of organisation according to the above definition, it is possible to operate with three categories: element, relation, and property. The complete specification of these categories will determine the organisation system through its development.

The representation of *M* elements, the relations between them *R*, will determine the universe of system properties *P*:

$$P = M \times R \tag{1}$$

and the Cartesian product

$$S = M \times R \times P \quad (2)$$

Determine the set of objects and their inherent phenomena concerning the complex hierarchical system S. It follows from the expression (2) that a specific complex hierarchical system of the organisation will be uniquely determined only in the case when given subsets of the elements of $M = \{m_1, \ldots m_i\}$, relations between them $R = \{r_1 \ldots r_j\}$ and properties $P = \{p_1 \ldots p_k\}$. At the same time, the specified sets are finite and can be described informatively when the level of detail of the system elements is determined.

A system with properties P can be obtained in development management only if the set S is not empty. That is, for equation (1), the universe of the system will include

$$P \subset M \times R \quad (3)$$

which indicates the existence of such a subset of elements M and relations between them R on which the development of this complex system is possible. A hierarchical system may contain several specified subsets, which indicates a multi-vector paradigm for developing such systems. Nonetheless, the general concepts (1) - (3) enable us to consider this process discretely, by separate vectors.

Mathematical representation of a complex hierarchical system

Consider the set S as a complex hierarchical system consisting of nodes that interact with each other but are, to a certain extent, independent. In the general cycle of goods or services production, they can create delays, change, or recover. In the specified system, some triggers of these processes can occur randomly. Perturbations in such a system are insignificant to a certain extent. The system is deterministic if the parameters are unchanged (Xing et al., 2019). However, disturbances that will lead to a change in parameters can cause not only the stoppage of a separate node but also problems in managing the entire system (Chueshov & Schmalfuß, 2020).

Consider a random process in some system node. Assume that this process occurs in a discrete phase space:

$$\mathcal{E} = \{0,1,2,\ldots\} \quad (4)$$

A number of time points of the system transition from one state to another is also discrete:

$$T = \{0,1,2,\ldots\} \quad (5)$$

Consider the process specified at the node through a random variable corresponding to the number of the state where the system is at the moment of time ℓ. Denote through $E_{\ell i}$ the state of this node is summarised because, at the moment of time ℓ the system is in a state of impact i to the specified separate node:

$$E_{i\ell} \infty (\xi_\ell = i) \quad (6)$$

A complete theoretical-probabilistic description of the system evolution control development consists in determining the probability that for arbitrary time sets $\ell_1, \ell_2 \ldots \ell_k$ $(\ell_1 < \ell_2 < \ldots < \ell_k)$ for separate nodes of the system and the effects on these nodes from the side of the system $i_1, i_2 \ldots i_k$ the occurrence takes place:

$$E_{\ell_1 \ell_2 \ldots \ell_k, i_1, i_2, \ldots i_k} = E_{\ell_1 i_1} \cap E_{\ell_2 i_2} \cap \ldots \cap E_{\ell_k i_k} = \bigcap_{t=1}^{k} E_{\ell_t i_t} \quad (7)$$

Thus, at a given k moments of time, the S system exerts a specific management influence on separate nodes, which generally forms a paradigm for developing the entire hierarchy of individual organisational elements. The probability of the event (7) can be calculated through the conditional probability system. At the same time, there is a class of random processes for which the necessary description can be obtained more simply. For example, this is a class of Markov-chain probability distribution (Munkhammar & Widén, 2018), which can be considered flexible models of individual business processes with varying management models depending on the situation.

Such modelling can be carried out using Vensim Front Page tools, which allow the building of flexible models with a flexible distribution of resources concerning managing a complex system.

Analysis of the company's business processes according to the optimality criterion

Consider managing the development of a complex system S according to the optimality criterion. Then, each node acts as a subdivision n that uses m types of resources (raw materials, energy, labour) for its work. The matrix of resource-specific costs for producing goods or services is known*: i=1,...,m* – resource number; *j=l,...n* – a sign of a subdivision performing some BP *N*. If the volumes of all available resources b_i and prices c_j (profit rates) for each product or service are known, an optimal plan for performing works/services can be drawn up. For this, the company's work can be represented by a vector of variables x_j*:* x_1*,* x_2*,* ...x_n*,* describing the amount of work performed. The company's total income $\sum_{j=1}^{n} c_j x_j$ will be the sum of the profits of individual subdivisions c_j x_j according to their contribution to the formation of profit in the general business process *N*.

Then, the costs for each type of resource will be:

$$\sum_{j=1}^{n} a_{ij} x_j \quad i = 1, \dots m$$

Moreover, the optimality model will look as follows:

$$f(x_1, x_2, \dots x_n) = \sum_{j=1}^{n} c_j x_j \rightarrow max \tag{8}$$

At the same time:

$$\sum_{j=1}^{n} a_{ij} x_j \le b_i \qquad i = 1,2, \dots m \tag{9}$$

i.e., general resources cannot exaggerate available volumes, and

$$x_j \ge 0 \qquad\qquad j = 1,2, \dots n \tag{10}$$

which denotes the participation of each separate company division in implementing production activities according to the business process *N*.

The problem (8) can be presented linearly:

$$f = c_1 x_1 + c_2 x_2 + \dots + (min) \tag{11}$$

where the constraint system is expressed as follows:

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \ge (\le) b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \ge (\le) b_2 \\ \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \ge (\le) b_n \end{cases}$$

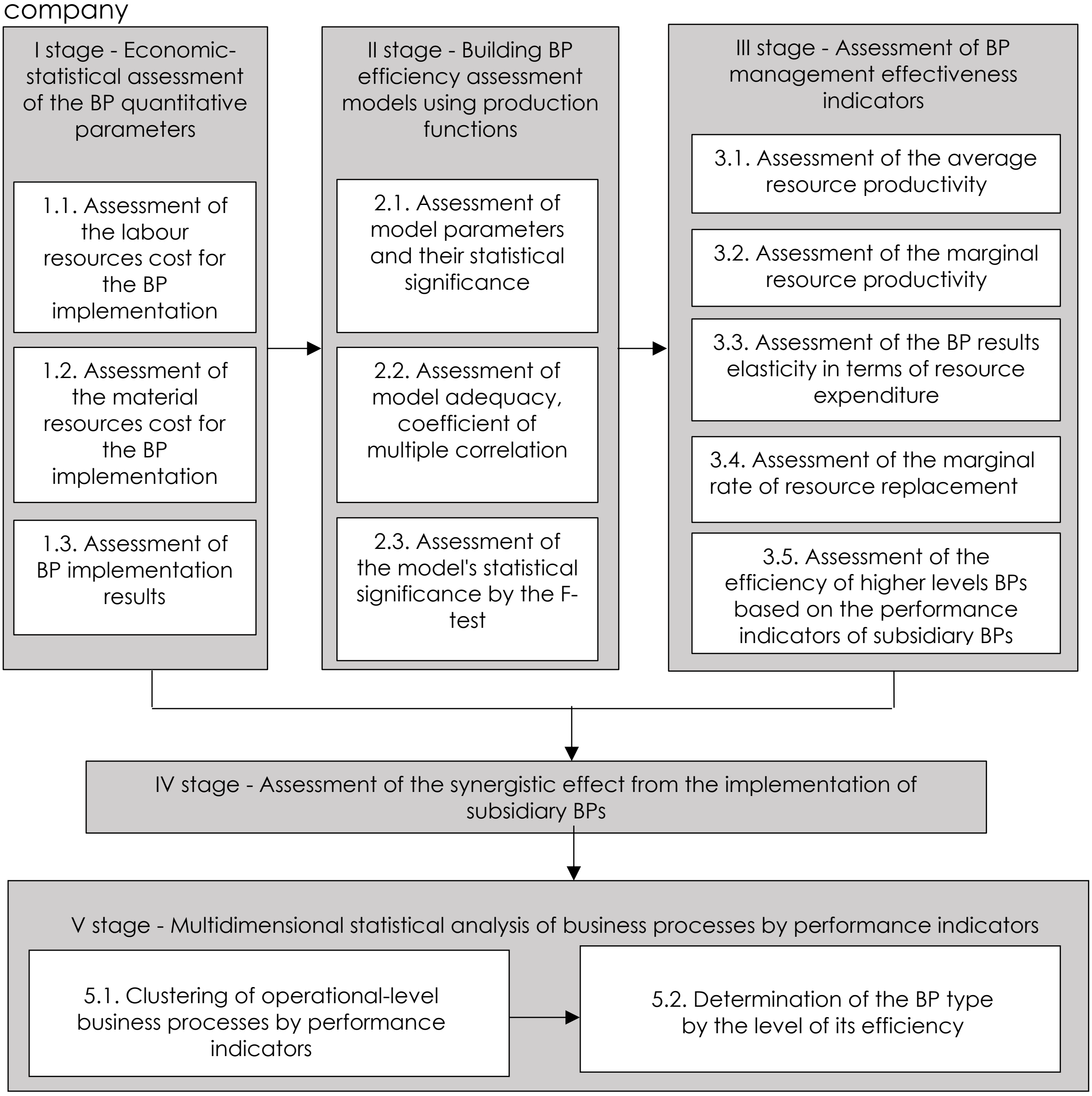
when performing (10). Problem (11) will be a classic optimisation problem based on the conditional extremum of many variables' functions (Kimiaei et al., 2022). Such an approach makes it possible to identify business processes that are the basis of the company's profit. However, it is difficult to adjust due to the inability to dissect tactical and strategic business processes at the level of a separate structural unit of the company, which is a hierarchical system. Changing the business process management system (BPMS) structure requires adjusting the set of models that describe the functioning of a complex system, considering the levels of hierarchies. In this case, it is possible to calculate the total efficiency of tactical and strategic business processes through subsidiary processes. Thus, a shift in the assessment criterion from optimality to the efficiency of a separate process is possible.

Management of the company's processes according to the efficiency criterion

Based on the research of BusinessNews Publishing (2014) and Ilmudeen (2022), the overall assessment of the IT service company's strategic business process effectiveness depends on the efficacy of each subsidiary BP. That is, the BPMS centre's effectiveness in the IT service company is determined by considering the effectiveness of all other system elements: the purpose of the BPMS operation is to achieve the maximum level of strategic BP efficiency. Therefore, the effectiveness of the IT service company's entire BPMS begins with the efficacy of the lowest-level activities and business processes. Considering the accepted hierarchical structure of the BPMS, the lowest level of consideration is BP's operational level.

It is proposed that the effectiveness of the operational-level BP be evaluated concerning the amount of labour and material resources spent on the business process. Figure 1 displays the general mechanism for assessing the efficiency of business processes in the IT service company.

Figure 1
Mechanism for assessing the efficiency of business processes in the IT service company



Source: Authors' work

Ten leading IT service companies in Ukraine were reviewed using the specified mechanism (Figure 1) and considering approach (8). According to the State Statistics Service of Ukraine, their list and performance indicators for 2022 are shown in Table 1.

Table 1
List of leading IT service companies in Ukraine

Company name	Net income in 2022, million USD
EPAM Systems	625.0
GlobalLogic Ukraine	356.0
Luxoft Solutions	184.0
Ciklum	149.0
Intellias Institute of Information Technologies	126.0
Infopulse Ukraine	104.0
LOHIKA LTD LLC	93.0
Sigma Software	61.0
Grid Dynamics Ukraine	51.0
Astound Commerce	46.0

Source: According to data from the State Statistical Service of Ukraine (n.d.)

To better understand the impact of business processes and resource allocation for each of the companies mentioned above, one can analyse them using the concept of production function. This helps to establish a clear relationship between input resources and output results (Sickles & Zelenyuk, 2019). Considering the rapidity of technology development in the IT industry, especially in the provision of service services, the Cobb-Douglas production function in the form of J. Tinbergen (Wang et al., 2021) should be chosen as a modelling tool in the study (Wang et al., 2021), which takes into account the impact of technological progress (Biddle, 2020).

Result dependence characterisation of processes and resources for an IT service company

In general, the mathematical model of the Tinbergen production function (Wang et al., 2021) can be represented by the expression:

$$Y = A \cdot e^{\rho \cdot t} \cdot L^{\alpha} \cdot K^{\beta} \tag{12}$$

where:
α, β – output elasticity by factors;
$A \cdot e^{\rho \cdot t}$ – the level of technical progress at A<0;
ρ>0 – means the rate of technological development.

The study used time expenditure (*zp*)and capital expenditure (*zm*) as production factors for BP's activities (actions) to build a dependency model. The result factor is the value of the integral assessment of the satisfaction level with the BP e_{ijk}^{t} results. Considering the above, the research used a general mathematical model for assessing the effectiveness of BP in the following form:

$$e_{ijk}^{t} = A \cdot e^{\rho \cdot t} \cdot zp^{\alpha} \cdot zm^{\beta} \tag{13}$$

For the study, the effectiveness of BP was assessed using the Statistica *software package* in the Non-Linear Estimation module for a generalised complex hierarchical system of an IT service company. Table 2 summarises the results of building the obtained mathematical models into production functions.

Table 2
Results of modelling assessment of operational level BP efficiency

BP designation	BPs name	A model for assessing the BP effectiveness	*d*	*R*	*F*	*p-value*
A1	Marketing					
A1.1	Market research	$e_{11}^{t} = 0.024 \cdot e^{0.85 \cdot t} \cdot zp_{11}^{0.087} \cdot zm_{11}^{0.891}$	0.77	0.877	964.8	0.0031
A1.2	Lead generation					
A1.2.1	Lead generation via company email	$e_{121}^{t} = 0.19 \cdot e^{1.13 \cdot t} \cdot zp_{121}^{0.097} \cdot zm_{121}^{0.107}$	0.97	0.985	9666.67	0.00
A1.2.2	Lead generation via conferences	$e_{122}^{t} = 0.215 \cdot e^{0.93 \cdot t} \cdot zp_{122}^{0.104} \cdot zm_{122}^{0.091}$	0.87	0.933	764.78	0.012
A1.2.3	Lead generation via the website					
A1.2.3.1	Promotion through search engines	$e_{1231}^{t} = 0.233 \cdot e^{0.83 \cdot t} \cdot zp_{1231}^{0.084} \cdot zm_{1231}^{0.102}$	0.911	0.954	126.23	0.008
A1.2.3.2	Promotion via social networks	$e_{1232}^{t} = 0.385 \cdot e^{0.5 \cdot t} \cdot zp_{1232}^{0.12} \cdot zm_{122}^{0.039}$	0.76	0.872	274.7	0.047
A1.2.4	Lead generation through a partner program	$e_{124}^{t} = 0.27 \cdot e^{0.71 \cdot t} \cdot zp_{124}^{0.14} \cdot zm_{124}^{0.062}$	0.81	0.904	113.82	0.038
A1.3	Increasing brand awareness					
A1.3.1	Content distribution through thematic resources	$e_{131}^{t} = 0.25 \cdot e^{0.97 \cdot t} \cdot zp_{131}^{0.112} \cdot zm_{131}^{0.07}$	0.788	0.887	347.21	0.005
A1.3.2	Content distribution to leads (potential customers)	$e_{132}^{t} = 0.097 \cdot e^{0.56 \cdot t} \cdot zp_{132}^{0.082} \cdot zm_{132}^{0.522}$	0.825	0.908	965.83	0.027
A1.3.3	Mailing to existing contacts	$e_{133}^{t} = 0.47 \cdot e^{0.347 \cdot t} \cdot zp_{133}^{0.21} \cdot zm_{133}^{0.074}$	0.76	0.87	77.6	0.022
A1.4.	Content development	$e_{141}^{t} = 0.089 \cdot e^{0.745 \cdot t} \cdot zp_{141}^{0.354} \cdot zm_{141}^{0.479}$	0.79	0.889	105.33	0.047
A2	Sales					
A2.1	Customer engagement					
A2.1.1	Customer engagement through a tender	$e_{211}^{t} = 0.065 \cdot e^{1.03 \cdot t} \cdot zp_{211}^{0.107} \cdot zm_{211}^{0.604}$	0.81	0.9	119.36	0.029
A2.1.2	Customer engagement through open vacancies	$e_{212}^{t} = 0.128 \cdot e^{0.43 \cdot t} \cdot zp_{212}^{0.04} \cdot zm_{212}^{0.642}$	0.837	0.915	143.78	0.028
A2.2	Contract signing	$e_{22}^{t} = 0.116 \cdot e^{0.453 \cdot t} \cdot zp_{22}^{0.63} \cdot zm_{22}^{0.17}$	0.78	0.887	99.27	0.047
A2.2.1	Signing a support contract	$e_{221}^{t} = 0.186 \cdot e^{0.453 \cdot t} \cdot zp_{221}^{0.53} \cdot zm_{221}^{0.24}$	0.91	0.954	283.11	0.019
A2.3	Preparation of the project start	$e_{23}^{t} = 0.426 \cdot e^{0.16 \cdot t} \cdot zp_{23}^{0.24} \cdot zm_{23}^{0.23}$	0.94	0.97	438.67	0.009
A3	Negotiations					
A3.1	Pre-Sale	$e_{31}^{t} = 0.355 \cdot e^{0.312 \cdot t} \cdot zp_{31}^{0.48} \cdot zm_{31}^{0.123}$	0.74	0.86	79.69	0.048
A3.2	Elaboration phase	$e_{32}^{t} = 0.274 \cdot e^{0.184 \cdot t} \cdot zp_{32}^{0.19} \cdot zm_{32}^{0.25}$	0.757	0.87	87.22	0.042
A3.3	Upsales	$e_{33}^{t} = 0.155 \cdot e^{0.113 \cdot t} \cdot zp_{33}^{0.41} \cdot zm_{33}^{0.42}$	0.803	0.896	114.13	0.033
A4	Project implementation					
A4.1	Project development	$e_{41}^{t} = 0.268 \cdot e^{0.77 \cdot t} \cdot zp_{41}^{0.104} \cdot zm_{41}^{0.094}$	0.92	0.959	322	0.007
A4.2	Monitoring					
A4.2.1	Questionnaire PMO	$e_{421}^{t} = 0.54 \cdot e^{0.233 \cdot t} \cdot zp_{421}^{0.18} \cdot zm_{421}^{0.054}$	0.72	0.849	61.7	0.049
A4.2.2	Project Statuses	$e_{422}^{t} = 0.145 \cdot e^{0.253 \cdot t} \cdot zp_{422}^{0.187} \cdot zm_{422}^{0.46}$	0.879	0.943	194.18	0.027
A4.2.3	Status - meeting	$e_{423}^{t} = 0.179 \cdot e^{0.173 \cdot t} \cdot zp_{423}^{0.23} \cdot zm_{423}^{0.411}$	0.69	0.831	62.32	0.047
A4.2.4	Delivery status-meeting	$e_{424}^{t} = 0.384 \cdot e^{0.03 \cdot t} \cdot zp_{424}^{0.14} \cdot zm_{424}^{0.2}$	0.71	0.84	68.55	0.042
A4.2.5	Process adjustment	$e_{425}^{t} = 0.14 \cdot e^{0.57 \cdot t} \cdot zp_{425}^{0.081} \cdot zm_{425}^{0.322}$	0.95	0.975	532.22	0.007
A4.3	Support	$e_{43}^{t} = 0.486 \cdot e^{0.032 \cdot t} \cdot zp_{43}^{0.18} \cdot zm_{43}^{0.12}$	0.88	0.938	205.33	0.036

Source: Authors' work

High-quality indicators characterise the resulting models. The evaluation criteria are the determination coefficient, the coefficient of multiple correlation, the F-test and its *p-value* significance level. The coefficient of determination for the built models exceeds 0.7, characterising a high level of model adequacy. The coefficient of multiple correlation is high and close to 1, which indicates a strong influence of model factors on the resulting indicator. The value of Fisher's criteria in the models is high and exceeds critical levels, which is confirmed by the low level of the *p-value* criterion. Thus, we can conclude that the built models are of high quality, which makes it possible to use them for further BP optimisation. A simulation modelling approach based on an aggregated model of dynamic processes, characteristic of all reviewed IT service companies, was applied for optimisation.

Results

Basic model

If models (8) – (10) are considered, then within the functional structure, the efficiency function of each BP will have the form:

$$e_{ijk}^{t}\left(A_{ijk}^{t}\right) = f\left(zp_{ijk}^{t}(\bullet), zm_{ijk}^{t}(\bullet), s_{ijk}^{t}(\bullet)\right) \tag{14}$$

where the model (11) can be represented as

$$f\left(zp_{ijk}^{t}(\bullet), zm_{ijk}^{t}(\bullet)\right) = A \cdot e^{\rho \cdot t} \cdot {zp_{ijk}}^{\alpha} \cdot {zm_{ijk}}^{\beta} \tag{15}$$

at which $s_{ijk}^{t}\left(A_{ijk}^{t}\right)$ – will act as additional financing for a separate business process of the company at the *t* – time point to increase its efficiency.

Then:

$$\sum_i \sum_j \sum_k s_{ijk}^{t}\left(A_{ijk}^{t}\right) \leq \Delta_{ZM}^{t} \tag{16}$$

In this case $\Delta_{ZM}^{t} = ZM^{t} - \sum_i \sum_j \sum_k zm_{ijk}^{t}\left(A_{ijk}^{t}\right) > 0$ – the foundation surplus funds can be directed to additional financing in implementing low-performing subsidiary BPs.

The business processes group efficiency (or the entire system of company business processes) can be calculated as the arithmetic mean of the business processes efficiencies that make it up:

$$E_q = \frac{\sum_{i=1}^{n_q} e_i^{t}\left(A_{ijk}^{t}\right)}{n_q} \tag{17}$$

where:

q – group number;

n_q – number of BPs of this group.

Moreover, considering the specifics of the IT service companies functioning (Ilmudeen, 2022), concepts (1) – (3) and model (11), the task of the BPMS effective functioning will be to achieve the maximum level of BPMS effectiveness containing *N* processes:

$$E_N = \frac{\sum_{i=1}^{N} e_i^{t}\left(A_{ijk}^{t}\right)}{N} \rightarrow max \tag{18}$$

where the constraints system will be represented by labour and financial resources:

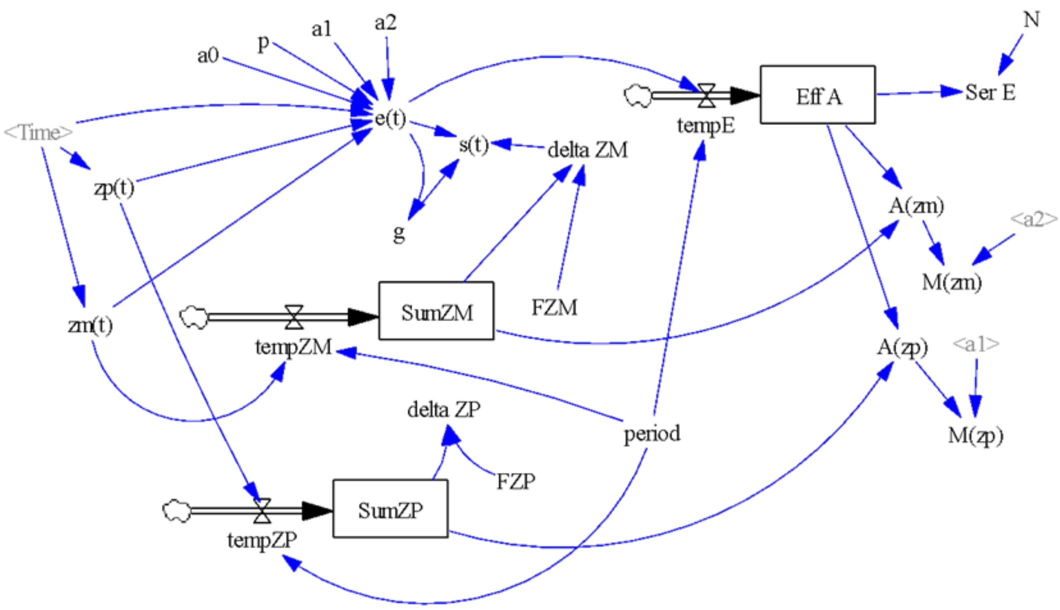
$$\sum_i \sum_j \sum_k zp_{ijk}^{t}\left(A_{ijk}^{t}\right) \leq ZP^{t}$$

$$\sum_i \sum_j \sum_k zm_{ijk}^{t}\left(A_{ijk}^{t}\right) \leq ZM^{t}$$

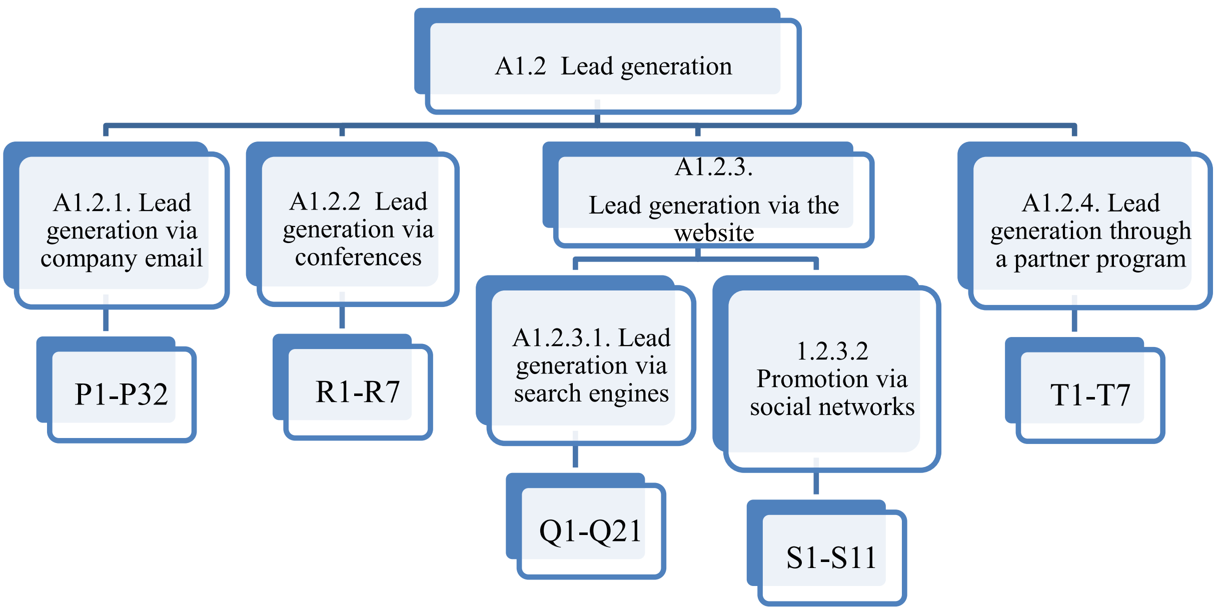
$$\Delta_{ZM}^{t} = ZM^{t} - \sum_i \sum_j \sum_k zm_{ijk}^{t}\left(A_{ijk}^{t}\right)$$

The system dynamics method was used to build the model, following the approach detailed in Palm's work (2021). Considering the correlations (12) - (16) given above, the basic model of an IT company's business process management can be presented as a flow diagram (Figure 2).

Figure 2
Flow diagram of the basic model IT company's business process management (a) and structure of BP "Lead generation" (b)



a)



b)

Source: Authors' work

The head of the Marketing Department (), Operating Director (), Commercial Director (), Researcher (), Analyst (), SEO (Outsourcer) (), and Sales Manager (USA) () perform BP activities.

The presented model included several variables reflecting the peculiarities of BP in IT companies (Schweikl & Obermaier, 2020), which are listed in Table 3.

Table 3
Variables of the basic model of IT company business process management

Variable designation	Variable type	Variable name	Calculation method/formula
Time	Time component	Moment of time	One month with a daily saving of results
zp(t)	Controlled variable	Time spent on the activity	Depends on activity, output data
zm(t)	Controlled variable	Current expenditure of funds for performance of activity per unit of time	It depends on the qualification of the activity performer
a0	Constant	Parameters of the Activity Efficiency Evaluation Model	Defined for each BP
p	Constant		
a1	Constant		
a2	Constant		
e(t)	Computed variable	activity effectiveness	Determined by the formula (13)
s(t)	Computed variable	additional financing of the activity at *t–time* to increase its efficiency	s(t)= delta ZM* g
g	Controlled variable	the share of funds of the saved fund, which must be directed to increase the efficiency of the business process	It depends on the BP efficiency level and its priority
SumZP	Level	The total time spent on performing process activities	TempZM amount for the entire period
SumZM	Level	The total cost of financial resources for the performing process activities	TempZM amount for the entire period
tempZM	The tempo of filling the level	Expenditure of funds for activity at the current moment	Is equal to the current expenditure of funds per unit of time zm(t)
tempZP	The tempo of filling the level	Time spent on the activity at the current moment	Is equal to the current time spent on the activity zp(t)
EffA	Level	Effectiveness of the entire VR	TempZM amount for the whole period
tempE	The tempo of filling the level	Value of BP efficiency at the current moment	Is equal to the current performance efficiency of the activity e(t)
FZP	Controlled variable	The fund of time for the BP implementation	Depends on BP, limitations
delta ZP	Computed variable	Saving time for BP implementation	delta ZP= FZP- SumZP
FZM	Controlled variable	Fund of financial resources for the BP implementation	Depends on BP, limitations
delta ZM	Computed variable	Fund economy the of financial resources by process	delta ZM= FZM- SumZM
period	Controlled variable	The periodicity of activity performance	Depends on activity, output data
Ser E	Computed variable	Average efficiency of BP	Ser E= EffA/ N
A(zp)	Computed variable	The average productivity of the performer's labour unit	A(zp)= EffA/ SumZP
M(zp)	Computed variable	Marginal productivity of the performer's labour unit	M(zp)= A(zp)*a1
A(zm)	Computed variable	Average productivity of financial resources unit	A(zm)= EffA/ SumZM
M(zm)	Computed variable	Marginal productivity of the performer's labour unit	M(zm) = A(zm)*a1
N	Constant	Number of BP activities	Depends on activity, output data

Source: Authors' work

The base model will be expanded according to the number of BP activities chosen by the modelling objects for each BP. A more detailed analysis is carried out for these objects by separating individual resulting clusters.

Business processes for the representation of individual clusters

In analysing ten leading IT service companies of Ukraine, followed by generalisation through a flow chart of the primary business process management model, BP clusters were identified according to resource utilisation efficiency. The processes of these clusters (Table 4) require changes in management methods.

Table 4
Characteristics of BPs requiring optimisation by clusters

BP group name	Designation and name of the BP representative	Type of BP based on cluster analysis results	BP management strategy
Group 2. Customer engagement processes	A3.1 Pre-sale	high-risk capital management business processes (type IV)	Optimisation of financial resources management
Group 5. Project diagnosis and adjustment processes	A4.2.2 Analysis of the Project Status	business processes of sufficient resource utilisation efficiency (type II)	Maintenance of the BP efficiency level
	A4.2.3 Discussion of the project status	high-risk business processes of personnel management (type III)	Financial, moral and ethical stimulation of employees
Group 10. Customer search processes	All subsidiary BPs A1.2 Lead generation	high-risk business processes of resource management (type V)	Optimisation and restructuring of BP

Source: Authors' work

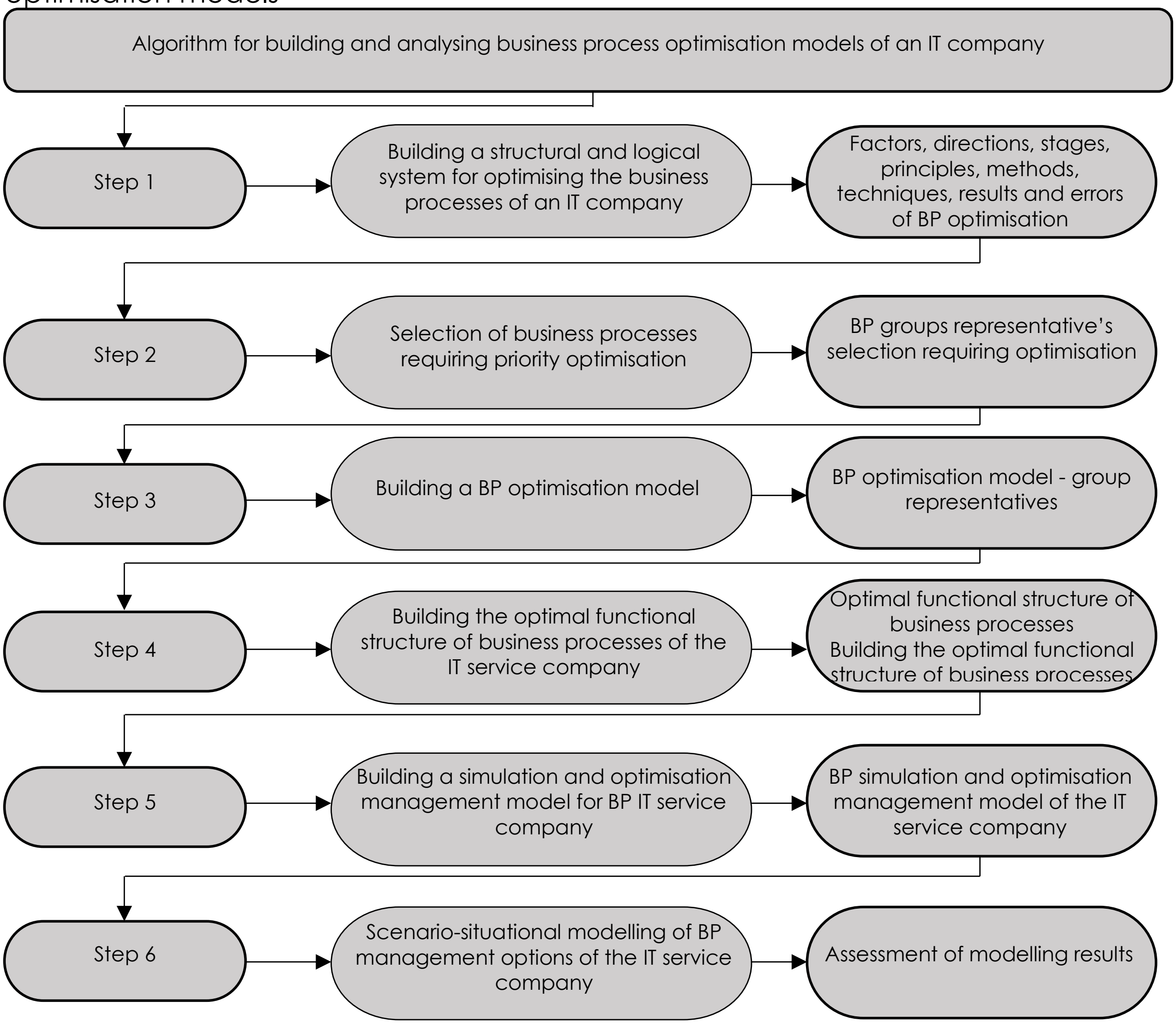
Process detailing by groups has the following characteristics:

- Group 2, which includes customer engagement processes, is also characterised by indicators of resource efficiency use below the average level. Therefore, the need to optimise high-risk capital management processes (type IV) is confirmed, to which the representative process A3.1 "Pre-sale" belongs
- Group 5, which holds the processes of diagnosis and adjustment of the project, is characterised by efficiency indicators that are below the average level for the structure as a whole, and therefore, its processes require optimisations. This group includes two representative processes. The first, A4.2.2, "Analysis of the project status", represents the cluster of business processes with sufficient resource utilisation efficiency (type II). The second, BP A4.2.3 "Discussion of the project status", is characterised by an increased risk of personnel labour management (type III)
- Group 10, which contains the business customer search processes, has significantly lower performance indicators. Thus, the need to optimise the A1.2 "Lead generation" processes of high-risk resource management of type V within the new structure is confirmed.

Algorithm for optimisation of IT company's business processes

The defined groups of business processes are characterised by low labour and financial resource use and excessive and high risk in their management. They require BP optimisation and restructuring considering activities, actions, their sequence, performers, and analysis of financial and information flows to identify redundancy and consider other aspects that directly or indirectly affect the BP implementation. Therefore, based on the activity analysis and features of the BP flow in the researched IT service companies and selected BPs that need optimisation, an algorithm for building and analysing optimisation models of the IT company's business processes was developed (Figure 3).

Figure 3
General algorithm for building and analysing IT company business process optimisation models



Source: Authors' work

The essence of the given algorithm (Figure 3) is as follows: an analysis is carried out, and a stationary situational model with dynamic feedback on the output vector is built. Implementing the algorithm results in building a BP control model with linear feedback on the state vector. At the same time, a closed system with occurrences of the type (7) receives a BPMS according to model (16), which has a stationary probability distribution of possible control model options for individual BPs, which are representative of clusters where problems are detected.

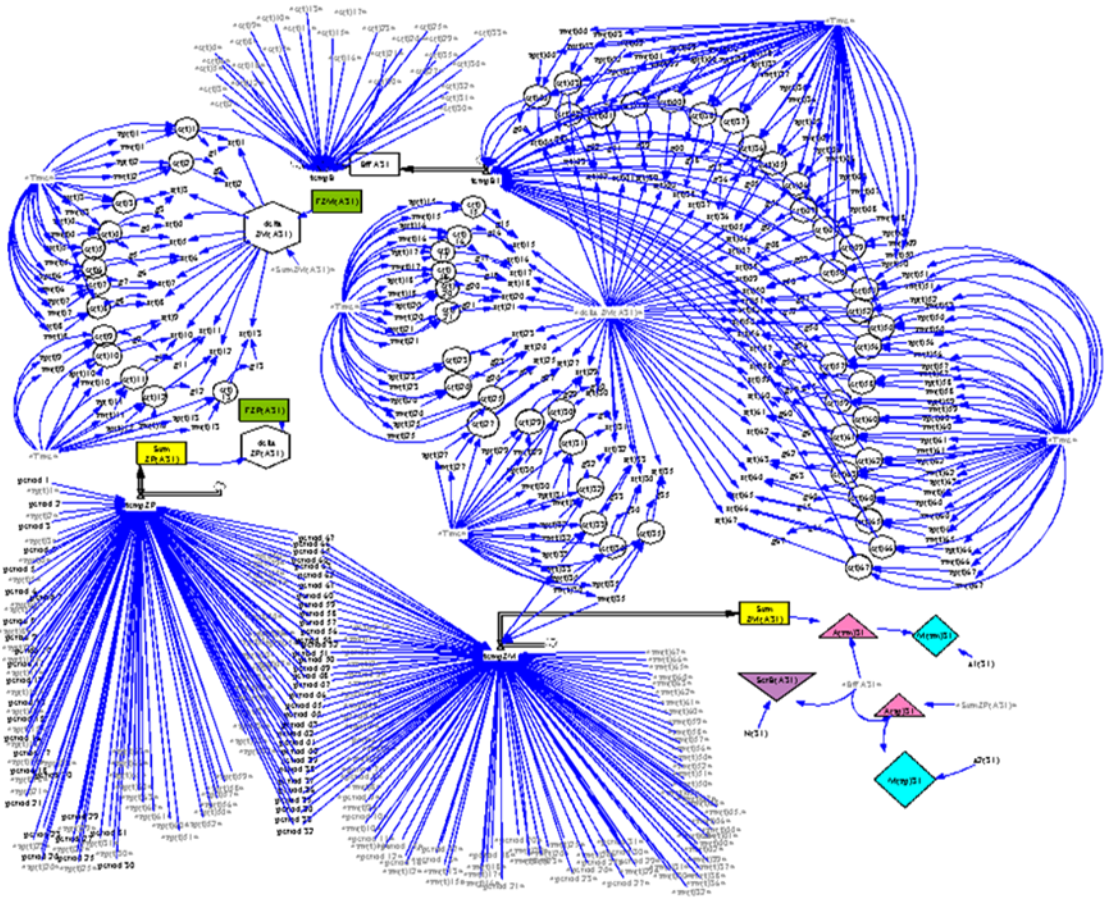
Implementing a similar algorithm regarding Table 3 confirms the need for further optimisation of BP with high and increased resource management. In particular, the solution will be building simulation and optimisation management models of BP A1.2

"Lead generation" and A3.1 "Pre-sale."

Simulation model design for managing the development of a complex hierarchical system

The simulation model developed for BP A3.1 Pre-sale using the system dynamics method (Brumar, 2010) and considering the BP peculiarities in IT companies (Schweikl & Obermaier, 2020) contains 371 variables. The general diagram of the model is revealed in Figure 4.

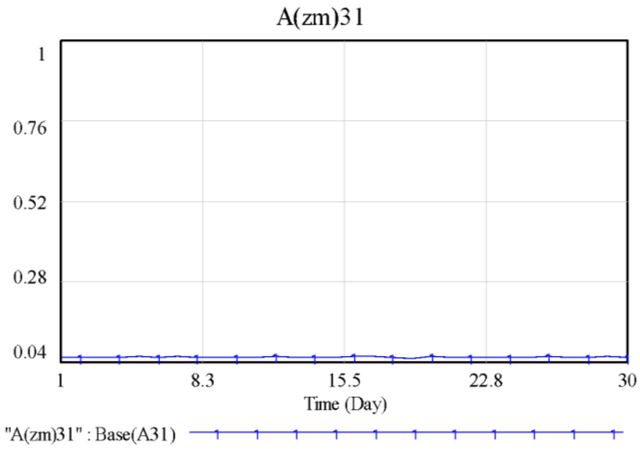
Figure 4
Flow diagram of the BP A3.1 management simulation model



Source: Authors' work

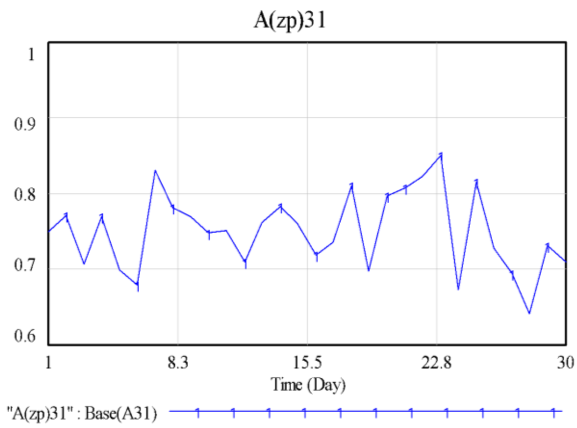
The developed algorithm (Figure 4) was implemented in software, allowing the primary run to be simulated. As a result, the following results of implementing BP A3.1 were obtained (Figure 5 - 9).

Figure 5
Dynamics of the model values of the financial resources' average productivity by project, unit/conditional units



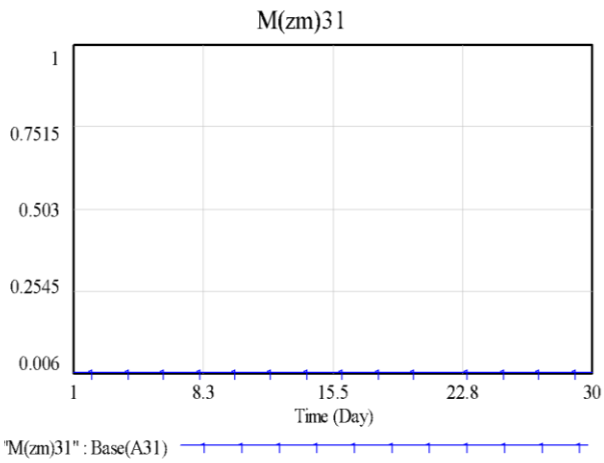
Source: Authors' work

Figure 6
Dynamics of model labour cost values average productivity by project, unit/hour



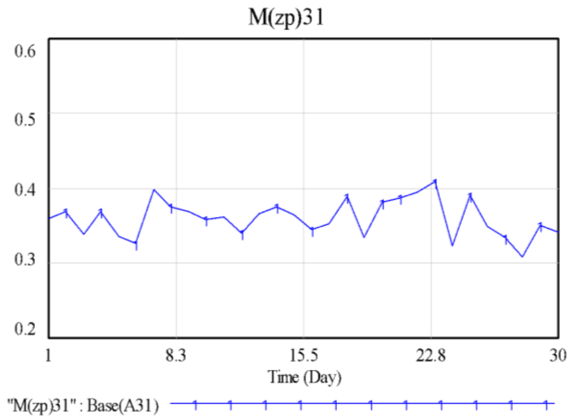
Source: Authors' work

Figure 7
Dynamics of model values of the financial resources' marginal productivity by project, units/conditional units



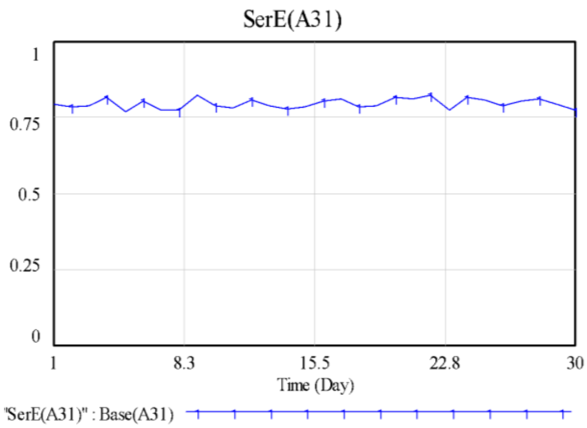
Source: Authors' work

Figure 8
Dynamics of the model values of the financial resources' marginal productivity by project, unit/hour



Source: Authors' work

Figure 9
Dynamics of model values of the efficiency average level of the project A3.1, units



Source: Authors' work

Table 5 presents the assessment of the adequacy of the built simulation model for managing BP A3.1 using indicators of average absolute and average relative modelling error.

Table 5
Assessment of the adequacy of the built simulation model for BP managing A3.1

Indicator	Denotation and obtained model values of the resulting model variables					Average deviation
	A(zp)31	M(zp)31	A(zm)31	M(zm)31	SerE(A31)	
Average model values for the modeling period	0.750	0.360	0.053	0.007	0.795	-
Actual values	0.724	0.348	0.054	0.007	0.79	-
Absolute deviation, units	0.026	-0.012	0.001	0.000	-0.005	0.02
Relative deviation, %	3.52	-3.32	1.06	-6.25	-0.59	-1.12

Source: Authors' work

Thus, the given approach and the developed means of simulation modelling helped predict the results of managerial influences on specific activities of business processes requiring optimisation. The simulation experiments for both business processes were determined as optimal by using the average percentage deviation of the resulting indicators of the built models as a criterion of optimality. These experiments were selected based on their ability to minimise the chosen criterion. The obtained results are shown in Table 6.

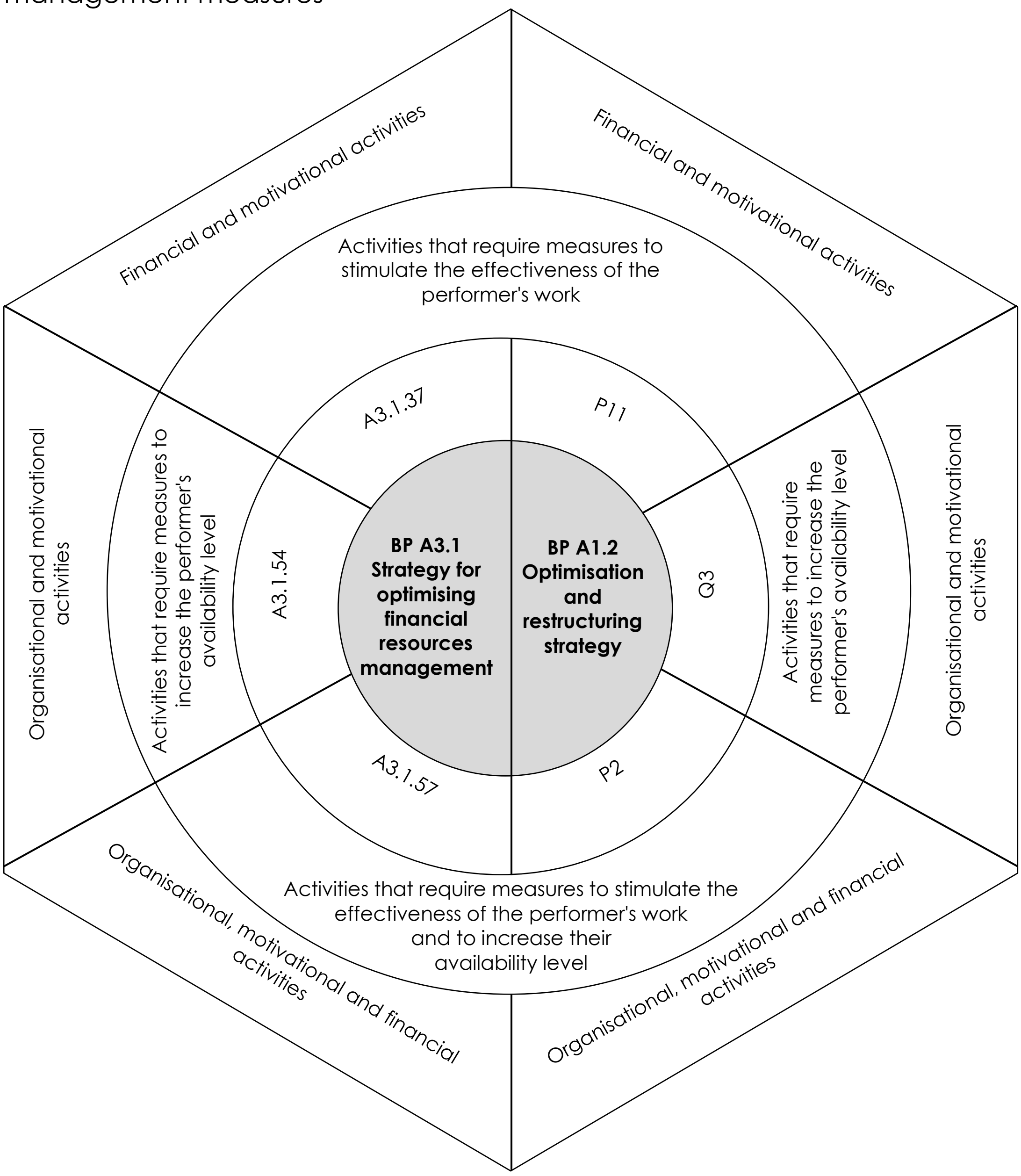
Table 6
Results of simulation experiments on business process management A1.2 "Lead generation" and A3.1 "Pre-sale"

Activity designation	Activity characteristics	The purpose of simulating management effects	An experiment with the best results	Predictive value of a variable e(t), %	The average growth rate of the resulting indicators, %	Conclusion about the results of the experiment
A3.1.37	the lowest satisfaction level with the result (60%)	To increase the efficiency of the activity due to the financial stimulation of the performer	Exp(3.1)-3 g(A3.1.37) ↑ on 15%	72.6	5.55	The goal has been achieved
P11	the lowest satisfaction level with the result (60%)		Exp(A12)-1 g(P11) ↑ on 5%	62.6	-5.89	The goal was achieved under the condition of excessive additional funding
A3.1.54	the lowest level of resource availability (40%)	To increase the efficiency of the activity by reducing the performing time to increase the performer availability level	Exp(3.1)-4 zp(t)(A3.1.54) ↓ on 5%	73.8	-0.72	The goal has not been achieved
Q3	the lowest level of resource availability (60%)		Exp(A12)-5 zp(t)(Q3) ↓ on 10%	74.4	-0.13	The goal has not been achieved
A3.1.57	the lowest level of resource availability (50%) and low satisfaction with the result (70%)	To increase the efficiency of the activity due to the performer's financial stimulation and reduction of the activity performance time to increase the performer availability level	Exp(3.1)-7 g(A3.1.57) ↑ on 15% zp(t)(A3.1.57) ↓ on 5%	76.06	2.88	The goal has been achieved
P2	the lowest level of resource availability (40%) and low satisfaction with the result (65%)		Exp(A12)-9 g(P2) ↑ on 15% zp(t)(P2) ↓ on 5%	65.37	0.12	The goal was achieved under the condition of excessive additional funding

Source: Authors' work

The analysis results of the conducted experiments made it possible to form an optimal subset of management influences for each activity according to its type and the BP optimisation strategy of which it is a part and to build a hexagon to form optimal business process management measures (Figure 10). At the same time, the main emphasis should be placed on improving the strategy of managing financial resources through its optimization and restructuring strategy. It was considered through the prism of optimizing organizational and motivational measures and increasing the general accessibility level of performers to the relevant BPs necessary for effective management.

Figure 10
Hexagon formation of the IT service company's optimal business process management measures



Source: Authors' work

From the analysis of Table 6 and Figure 10, it can be noted that the simulation experiments, the purpose of which was to reduce the time to perform the activity (A3.1.54 and Q3), did not give positive predictions. That indicates the ineffectiveness of using only moral and psychological encouragement measures to increase the productivity of IT company staff. Predictive evaluations of the solutions proposed for activities P11 and P2 of the business process A1.2 "Lead generation" turned out to be low due to the discrepancy between the growth rates of material incentives and the performer's work, regardless of their position. Predicting the effects on activities A3.1.37 and A3.1.57 gave positive results. The goal of increasing the activity's effectiveness was achieved, which indicates the reliability and efficiency of the selected management decisions.

Discussion

In the work, the organisation is considered a complex hierarchical system. The basis of the model presented in the paper was the assessment of business processes at different levels. This assessment became the basis for building a hierarchical model with a business process structure. The logical sequence of the assessment is followed: activity (separate for the business process) – business process of the operational level – business process of the tactical level – transition to the business process of the strategic level. That confirms the step-by-step nature of business processes and correlates with the work of Goel et al. (2021). The proven interrelationships between business processes made it possible to build a model of the optimisation mechanism of the company's IT management processes.

The developed model, represented in Figure 4 by the flow diagram of the BP A3.1 management simulation model with the following assessment of adequacy (Table 5), proved the proposed toolkit for managing the development of complex hierarchical systems to have relatively high accuracy. In particular, the given model allows the operation of the business processes of individual functional blocks of the hierarchical system, which is consistent with the conclusions of other researchers (Webler, 2022). However, this model's advantage is precisely the minimisation of information noise since the feedback is carried out according to the state vector, which considers information about the problem cluster.

Such block BP management has an advantage over models (Goel et al., 2021; Lee et al., 2019) when considering critical occurrences associated with the lack of financial resources or critical phenomena in HR management. As confirmed by Figure 10, utilising additional levers on activity, which require measures to stimulate performers' work (A3.1.37 and P11), can reduce the possibility of marketing turbulence. For example, in this case, financial and motivational measures will be optimal, which can include:

- A salary increase is the simplest and most effective way of motivation. It is formed by many factors, such as the enterprise size, the origin of the enterprise's capital, the field of activity, specific knowledge and skills availability, certificates, etc.
- The social package includes health insurance, payment for mobile phone calls, meals, fitness club membership, travel expenses, discounts on the company's goods and services, etc.
- The points accumulation system assigning points to the performer for the period of work in the company for participation in projects and other activities, which are then exchanged for any benefit at their discretion
- The incentives through the choice of equipment for work at their discretion at the company's expense, provided that it then becomes the employee's property.

Nevertheless, analysing the approach (Ilmudeen, 2022) and considering the model (Figure 10), it is necessary to reduce marketing turbulence, namely for IT service companies, to exert some influence on measures to increase the performer's availability level (A3.1.54 and Q3). Organisational and motivational measures will be optimal, including:

- Competent manager - For IT specialists, the leader's professional qualities are of great importance, as is the manager's ability to become an influential motivational factor for employees, especially in the IT industry. The information technology department is a relatively separate unit; it has its own rules, style of communication, clearly expressed specific interests, etc., so the manager needs to understand this

- Convenient location of the office, the possibility to work at home is a significant factor in reducing the time to complete the task
- Flexible and convenient work schedule - is an important motivating factor for any IT specialist, provides comfort and promotes an individual approach to optimising the employee's working capacity
- IT professionals' team – a way to gain the necessary experience and improve the skills
- Freedom in corporate communication – rejection of standards and regular meetings or brainstorming sessions for all in favour of groups or communities in messengers
- Distribution of tasks according to the employee's qualifications
- Non-financial encouragement of employees (shortened working day, an opportunity to hold a meeting, give a lecture, etc.)
- Promoting the development of time management skills, self-motivation and meeting deadlines among employees.

Considering the proposed management paradigm in terms of efficiency and business importance, as suggested by Shoukry et al. (2021), in addition to the mentioned author, it is possible to emphasise stimulating labour productivity and increasing the performer's availability level (A3.1.57 and P2). In this case, according to the model (Figure 10) and the conducted simulation experiments, organisational, motivational, and financial measures will be optimal:

- Introduction of a changeable bonus component into the salary for projects and non-standard tasks in addition to the mandatory norms
- Social package – payment of specialised it training, mobile communication, home internet and computer
- Ensuring comfortable conditions at the workplace - the opportunity to have a snack and rest in the office, providing a comfortable microclimate on the premises
- Use of effective work tools (appropriate modern software tools).

When creating a model to optimise an IT company's business processes, it is essential to consider the representatives of BP groups with an increased and excessive resource management risk. This model can determine the optimal number of performers required to ensure the minimum cost of implementation and the necessary level of performance efficiency for the chosen BP activities. Optimising representative processes led to a 3.26% increase in the company's entire BPMS efficiency, which was determined using the econometric models for assessing BP's effectiveness. The obtained simulation calculations were confirmed in practice in a Ukrainian IT service company AltexSoft. For the formed BP groups and the structure as a whole, an efficiency indicator was assessed based on the results of building econometric models, which showed an average increase in BP efficiency by 6%. The advantages of the BP's newly formed functional structure are:

- The implementation of a close connection between the BP of the highest management level and the BP that implements functional management
- Increasing the importance of functional managers
- Reducing the need for performers of a comprehensive profile
- Decreasing the time between decision-making and implementation
- Reducing intermediate links between the manager and the performer solutions

- Lowering the effectiveness dependence of some processes on others due to forming groups united by the type of performed functions.

Conclusions

The work proposed a general algorithm for building and analysing business process optimisation models of the IT company. The study identified groups of business processes that had a significant decrease in the level of utilization of the company's labour and financial resources. Also, these BPs were characterised by a high level of management risk, which had an impact on the management of the company. An IT company's business process management was analysed and optimised using simulation modelling and scenario modelling. That included a predictive assessment of management impacts on business processes to identify the most effective solutions for specific activities within individual clusters based on defined management strategies. The BP's management strategy and specific activity were considered while developing the optimal business process management measures for a service IT company. Based on the obtained results, a hexagon was formulated. It provides a set of measures to choose from, including financial and motivational, organisational, and motivational, or organisational, motivational and financial measures. The results obtained in the study became the basis for the formation of an optimal pool of management influences, considering the type and strategy of BP optimisation for each activity.

The limitation of the presented study is the use of average model values for the simulation period. That relatively generalises the obtained result but simultaneously allows the presentation of the situation in terms of basic processes in relation to any IT company. Thus, the article offers a significant scientific contribution by presenting a comprehensive model that IT companies can utilise to introduce and optimise various BPs. Consequently, critical processes in developing complex hierarchical systems, which arise due to the systemic inconsistency of individual BPs or result from synergistic effects during the optimisation of other BPs, can be promising research on the specified topic.

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