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IMPROVEMENT IN THE METHOD OF CASE-BASED MANAGEMENT OF END-TO-END BUSINESS PROCESSES

The object of research is the processes of case-based management a set of interconnected end-to-end business processes of the enterprise. The study is devoted to solving the problem of case-based management of interconnected end-to-end business processes of the enterprise that use shared resources. Research in this area is aimed at developing models, methods and technologies used in the management of business processes of the enterprise.

The goal and main limitations of functional and process management in the form of a set of business processes that integrate the activities of the relevant divisions of the enterprise are determined and formally described. The main disadvantage of such management is associated with the mismatch between the existing organizational structure of the enterprise and end-to-end business processes that cover several of its divisions. Therefore, a transition from process to end-to-end business process management that use shared resources is proposed. This approach involves searching for and adapting of case-based, applying it and further preserving it. In conditions of restrictions on the execution of business processes, the use of a case-based reasoning allows increasing the efficiency of process management. An improvement of the method of case-based management of a group of end-to-end business processes is proposed. Unlike the existing one, it allows to determine the priorities of their access to resources, taking into account the restrictions on the time of their execution. This ensures the execution of processes within the established deadlines, which improves the economic performance of the enterprise.

Practical application of the proposed improved method of case-based management of a group of end-to-end business processes allows to adjust the sequences of orders launch orders. This is done taking into account the restrictions on the execution time of each of the business processes, which allows to improve the process of order management at the enterprise.

Keywords: *process approach, data analysis, case-based reasoning, priorities, management method, resources.*

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1. Introduction

The activities of any enterprise are primarily focused on the production of products needed by the consumer and making a profit. In the work [1], the existing theoretical provisions and methodological recommendations on the application of a system-functional approach in the management of enterprises were improved. Based on the results of the conducted research, a model for regulating the effectiveness of the application of a system-functional approach in the management of innovative development of enterprises was developed. However, the problem of consumer satisfaction is not considered, which is possible when considering business processes at the enterprise. Therefore, the implementation of process management involves building a description of the enterprise as an object of management in the form of a set of business processes, which allows integrating the activities of its relevant divisions and ensuring an increase in the efficiency of the functioning of the enterprise as a whole. In the work [2], it is shown that the results obtained are too subjective, unable to identify hidden risks and it is concluded that the business process approach identifies more risks than the structural approach.

For a clear presentation of process management of business processes, the following definitions have been introduced:

– order – documentary confirmation of the manufacturer for the release of goods, which is implemented from the moment of conclusion of the contract by performing the production process to the shipment of finished products to the consumer;
– an end-to-end business process is similar to all stages of order implementation with the definition of the process owner, the necessary financial, material, labor resources and time constraints for its implementation;
– an end-to-end business process is represented by an ordered sequence of individual business processes that are identified with individual elements of the production process;
– a business process is implemented by appropriate actions.

The experience of enterprise management shows that the key problems of implementing a process approach are associated with the discrepancy between the existing organizational structure, focused on performing functional tasks within individual divisions, and end-to-end business processes that cover several divisions. In practice, end-to-end business processes use shared resources, which can lead to delays in accessing these resources and, as a result, untimely completion of these processes, increased costs and reduced profits for the enterprise.

Therefore, process management must take into account the interaction between different end-to-end business processes. However, due to insufficient formalization of the interaction between such processes, process management is implemented using practical experience and existing engineering practices. This indicates the importance of formalizing such experience, presenting it in the form of solutions based on existing cases, and their further use in process management. Formalization of case management allows to describe the implementation of the full management cycle from setting goals to planning tasks, monitoring

their implementation and their subsequent adjustment if necessary. Of course, such studies are important and relevant in the development of the theory of management of such complex processes. In general, the process approach involves managing a system of interconnected business processes that implement all types of enterprise activities and solve functional problems through the interaction of performers from its various divisions. In [3], the essence of a business process is defined as a sequence of actions aimed at achieving a goal within the framework of the enterprise's overall mission – providing quality services or producing products. This means ensuring a continuous ongoing production process that involves managing flows at inputs and outputs, has a responsible performer and an economically measured result.

It is indicated that the application of the process approach and optimization of business processes have a number of advantages for enterprise management. They help to understand the full context and logic of actions of all interconnected processes, improve coordination and communication between departments and employees, reduce the time for completing tasks and increase the quality of products or services. That is, there is a set of different types of activities within which one or more types of resources are used "at the input", and as a result of this activity "at the output" a product is created that represents a certain value for the consumer. In addition, the process approach and optimization of business processes contribute to continuous improvement, which allows the enterprise to be competitive in a constantly changing market environment. But there is no formal description and assessment of the enterprise's business processes taking into account the specifics of its activities.

The process approach makes it possible to eliminate the shortcomings of functional management by building a system of effective horizontal connections, and the internal environment of the enterprise as an object of management is considered as a system of processes. In order to achieve the goals of the enterprise in the process approach, it is necessary to manage business processes and organize their interconnected execution. In [4] the following problems of business process management are formulated:

– expansive BPM, which is considered in the form of fragments of processes, seeing the "process tree", and not the entire "BPM forest";
– creation of value from data based on BPM, which requires deep changes in the methods of managing business processes;
– automated (re)design of processes, which is associated with the widespread implementation of information systems in the context of process operations;
– construction of digital twins by coordinated changes in norms, instructions, policies or IT systems;
– lack of objectivity in process descriptions;
– fixed levels of granularity for process analysis during pre-processing;
– employee-oriented process management;
– implementation of data mining processes using stochastic data is associated with the growth of data volumes about events generated from several sources. To increase the efficiency of the enterprise, the problem of managing not individual processes, but the development of a business process management system is considered. This is the approach used in [5].

In [6], within the framework of solving the problem of automated business process management to increase the efficiency of the enterprise, the following sequence of tasks is defined:

– definition and description of existing business processes and their interaction;
– development, analysis and verification of business process models with the definition of performance indicators, methods for measuring indicators, as well as management responsibilities;
– configuration of business processes using information and analytical system tools with the development and approval of relevant regulations for formalizing the system;
– execution and monitoring of business processes;
– analysis of the results of execution and the formation of proposals for the reorganization of business processes;
– resource management and adjustment of regulations if deviations from the normal course of the process are detected. The implementation of this sequence of business process management requires modeling of the enterprise infrastructure, as well as individual processes. This issue is considered in [7]. In [8], when conducting a study of the processes of enterprise operation to increase its efficiency, they found a connection between cost and optimization using business process management. At the same time, there is a need for further and in-depth research into the relationship between cost aspects and business process management, especially in relation to the applications of information technology. The authors in [9] present the results of a study of instrumental aspects of business process management and their relationship with risk-adjusted company performance indicators, which take into account the required profitability in small and medium-sized enterprises. The main limitation is that they studied only the control activities of the main business processes and linked them to risk-adjusted company performance indicators. In addition, the results of this study cannot be generalized to large companies, because they have to deal with a greater division of labor, different approaches to business processes, deeper organizational structures, and stronger market positions.

Business processes allocated to the boundaries of divisions provide a local and fairly detailed description of the sequence of actions. However, if the users of business processes are located outside the divisions, such a description breaks the single sequence of actions, does not allow to see the picture as a whole, and, thus, complicates the management of such processes. To resolve this contradiction, end-to-end business processes are allocated that pass through the enterprise as a whole. End-to-end processes are processes that are performed within several divisions and ensure the integration of employee activities regardless of their subordination in the enterprise. The allocation of end-to-end processes is carried out according to the system approach, therefore, management considers the enterprise as a system of interconnected business processes without taking into account its functional structure. The main problem of managing end-to-end business processes is the need to build an adequate target process model. When designing such a model "from scratch" only on the basis of the experience of consultants, it is not always possible to ensure the specified level of efficiency of the enterprise. Therefore, in practice, usually after the first implementation of business processes, there is a need to carry out significant improvement or reengineering of such a process.

To reduce the costs of improving the model, it is advisable to use and adapt existing analogues or cases of business processes to the conditions of a particular enterprise. The construction and search for such analogues are implemented within the framework of the case-based, for which the process of solving a new task by reusing and adapting solutions previously obtained when solving similar tasks or problems is significant [10].

The case-based reasoning (CBR) is one of the approaches aimed at using existing experience, in particular, when implementing process management at new enterprises, solving new tasks that have implemented analogues. This approach can be compared to a certain extent with obtaining new and design solutions by adjusting previous solutions, which allows reusing and adapting projects to create new projects [11]. The use of cases in the integration of unknown speech knowledge retrieval with inferences based on graphical models in case-based reasoning is discussed in [12, 13]. In [14], the task of developing a dynamic balanced system of indicators using the method of case-based reasoning and an adaptive neurofuzzy inference system is considered. However, the question arises regarding the required number of such indicators for a separate subject area. The choice of explanation methods for intelligent Internet of Things systems based on case

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analysis is considered in [15], but there is a question regarding the correctness of the set of such methods. In [16], the results of studies of the influence of network architecture on the quality of extracted features for CBR are presented, but the complexity of such architecture is not specified. In general, the concept of process management of an enterprise, in contrast to the functional approach, first of all involves the construction of workflow models of work sequences that provide solutions to the corresponding functional tasks related to the production of products and services, administration, service, etc. Such work sequences that use resources to create products, services, etc. are represented by the business processes of the enterprise. After building business process models, further management of the enterprise is carried out by managing business processes. Such business process management consists in monitoring the executed sequences of actions of such processes and, if necessary, correcting these actions.

Of course, the effectiveness of management is determined by the timely achievement of the goals of the processes being performed. Therefore, the tasks of managing a set of coordinated business processes include not only the construction of a workflow model of the process, but also the search for "bottlenecks" in the production process with the subsequent forecasting of the duration of its execution.

To build business process models, both traditional approaches related to development "from scratch" and approaches that involve the use of existing process management experience are used. In the latter case, process models are adapted and replicated, which makes it possible to reduce the costs of implementing new business processes. Implementation of process management based on the case-based involves developing a model, performing a search and adaptation of a case, its application and subsequent storage. In this case, when implementing the case-based, the procedure for adapting the case is performed even before the start of managing the corresponding process. This makes it possible to adapt the management process and change the sequence of processes during execution, especially when accessing shared resources.

The development of models of the corresponding business processes is carried out using modern methods and tools for intelligent process analysis (Process Mining). Such models contain cause-and-effect relationships between events recorded in the event log of the corresponding information system. In [17], the authors developed a concept for effective management of the life cycle of an operated information system, which allows the dynamics to maintain records in the event log. In [18], the problem of creating an information system in the conditions of reuse of its functions is considered, which makes it possible to significantly reduce the time and costs for its maintenance and operation. In [19], a process model is considered, which is simulated to generate an event log that has certain properties defined by the user (for example, a certain number of traces, traces of a certain length, etc.). Generation methods have been developed that are available for both procedural and declarative modeling languages. However, they are limited to modeling one process model at a time and do not allow modeling the execution of several separate but interacting processes.

The issue of developing a Process Mining event log generator tool for creating Process Mining data files for the "order-to-cash" process is discussed in [20]. With this tool, users can create realistic datasets that include features such as segregation of duties, internal control violations, operational inefficiencies, and fraudulent behavior. However, training users to use it is a difficult task due to the lack of event data that is used to implement specific scenarios.

As is known, Process Mining methods are designed to build discrete models in the form of Petri nets, temporal logic models, etc. The business process case models obtained by analysis methods determine the sequence of solving the problem, but do not take into account the interaction of processes and the possibility of their use of common resources, which can lead to significant delays in the execution of such processes. In this case, there is no possibility within the case-based to solve the problem of managing a set of processes under the condition of changing the composition of the elements of this set. Therefore, the issue of adaptive management of a set of end-to-end business processes of an enterprise as elements of cases is relevant both from a theoretical and practical point of view.

The aim of research is to improve the process management method based on the case-based, which consists in selecting further routes for the execution of a group of business processes at the enterprise when changing the composition of this group. An indicator of increasing the efficiency of managing a set of business processes is 100% of their execution within the terms established by the contract, which improves the economic performance of the enterprise.

To achieve the aim, it is proposed to solve the following objectives:
- determine the main features of adaptive management of a set of end-to-end business processes of the enterprise;
- expand the content of the current case description model;
- conduct an experimental verification of the results of improving the method of case management of a set of end-to-end business processes.

2. Materials and Methods

The object of this research is the processes of case management of a set of interconnected end-to-end business processes of an enterprise that use shared resources. *The subject of the research* is a method of managing end-to-end business processes of an enterprise using a case-based.

The results of the analysis of materials from previous studies [21] allowed to establish the following features of case management of end-to-end business processes:
- are characterized by sets of sequences of actions wf_i, as well as their current state (performed actions) and have the following features;
- actions that use a common subset of j-th resources r_j belong to different business processes;
- priorities for access to resources are determined for the process as a whole and can change in order to minimize the waiting time for resources with restrictions on the execution time of each business process;
- when implementing each business process, only one sequence of actions is performed at each moment of time wf_i;
- due to the fact that sequences wf_i can have common actions, all such sequences must be taken into account;
- as the process is executed, the number of sequences reflecting possible options for the process development decreases.

To assess the state and case-based management of business processes, the following input data is required:
- process event logs are presented in the form of cases recorded by the corresponding information system;
- a subset of the set of case models of end-to-end business processes that are executed at the time of specifying priorities, obtained by Process Mining methods with the addition of process work execution intervals and resource waiting intervals;
- information about the current state of each of the business processes that are executed at the time of determining priorities is characterized by the process actions that were performed by the time of determining priorities;
- a list of common enterprise resources that are used by several end-to-end business processes, acting as constraints for end-to-end business processes;
- a list of objects (products, services) that are produced by the business process.

Of course, the cases, which are the main component of the case management, set the order and sequence of work for several options for implementing the business process. For each action of the process, the necessary resources are determined, which makes it possible to organize access to enterprise resources by determining priorities for each end-to-end business process in relation to each shared resource. That is,

in the case management of business processes, it is necessary to find such a "solution" in the form of changing the priorities of their access to each shared resource r_j in order to minimize the waiting time for resources with restrictions on the execution time of each of these processes

$$\min\left(\sum \tau_i^{wt}\right) \Big| \forall Bp_i, \quad \tau_i \le \tau_i^{\max}, \tag{1}$$

where τ_i^{wt} – total resource waiting time for the i-th business process Bp_i; τ_i – total business process execution time Bp_i in accordance with the dates set by the contract; $\tau_i^{\max}$ – business process execution time limit.

The waiting time for each business process is defined as the total waiting time for access to resources.

The obtained "solution" to the problem in the form of establishing priorities for business processes of access to each shared resource r_j is the main component of the case model, which is entered into the case database. In this case, cases set the order and sequence of work for several options for implementing the business process. For each process action, the necessary resources are determined, which makes it possible to organize their access to the enterprise's resources. For this purpose, a model and technology for determining priorities for each end-to-end business process in relation to each shared resource r_j have been developed in order to minimize deviations from the specified deadlines for their execution. The end-to-end business process model within the framework of this task is displayed as a set of alternative sequences of business process actions, each of which consists of resource waiting intervals and action execution intervals. The duration of the waiting intervals and the duration of actions, respectively, depend on the priority of access of business processes to shared enterprise resources. Therefore, when performing each sequence of actions, it is advisable to calculate the waiting interval taking into account the priority of access to the corresponding resources.

The features that allow determining the belonging of events to a business process are their attributes (name of the process operation; executor; object used by the process; name of the organization's division where the process is performed). In this case, events record the waiting time of each business process as the total waiting time for access to resources.

To solve the problem, variants of the control actions of the "solution" are defined in the form of setting priorities for access to common resources of competing business processes (competitive point), which would ensure their execution within the terms established by the contracts. At the same time, in some competitive points, the composition of business processes may change. This means that at any competitive point, a business process that does not compete with them for resources at previous points may be included in the group of executed business processes. Therefore, in the development of the method of operational case management, a model for finding the "controlling influence" is proposed, in the form of operational determination of priorities for launching orders in all competitive points, taking into account their standard time and remaining execution time.

In addition, the condition of execution of all key end-to-end business processes included in the group must be met in accordance with the terms established by the contracts. Non-key end-to-end business processes, simultaneously competing for common resources together with key ones at each competitive point, are managed by traditional methods. If it is necessary to change the status of a specific end-to-end business process related to economic parameters (profit, fines), the decision-maker can change the order of its launch at some competitive point.

To implement operational management of a group of end-to-end business processes, a case management method has been developed. It allows to adjust the priorities of access of processes to resources taking into account the restrictions on the time of their execution. The method formalizes the formation of a description of the current case, its comparison with a case – an analogue, and after its adaptation it is used as a controlling influence [21].

The method of case management of a group of end-to-end business processes includes the following stages:

Stage 1. Formation of parameters of a group of end-to-end business processes that characterize the state of their execution at the time of making a Decision on their management (z_i – number of the i-th order; r_{il} – resource of execution of the l-th business process of the corresponding i-th order; T_i^{set} – time of execution of the i-th order under the contract; t_{il}^h – normative time of execution of the l-th business process, i-th order; waiting time $t_{ij}^{p\,wait}$ for execution of the action; κ_{il} – order/priority of passing the l-th business process of the i-th order; $T_{k.i}$ – total actual time of execution of the i-th end-to-end business process).

Stage 2. Checking the condition of deviation of the total actual time of execution of the end-to-end business process $T_{k.i}$ and the time of execution of processes under the contract T_i^{set} at the current competitive point, $X = T_{k.i} - T_i^{set}$. If the value $x > 0$, then it is necessary to find a management "solution" Ps, in the form of establishing the order/priority κ_{il} of passing the l-th business process of the i-th order at the current point, which will allow eliminating this deviation.

Stage 3. Obtaining a model of the current case M_p^a of a group of end-to-end business processes.

Stage 4. Searching in the database of similar cases for such a model of description of the similar case M_p^a that coincides with the model of description of the current case M_p^n. If such descriptions of cases completely coincide, then the model of the existing solution Ps from the similar case is used as a controlling influence and the method is completed.

If there is no complete match of the models, then to adapt the current case model M_p^n, it is necessary to proceed to Stage 5.

Stage 5. Adaptation of the current case model is carried out by calculating the execution delays ΔT_k^c for the current business process $T_{k.i}$, comparing it with the term of its execution under the contract T_i^{set}

$$\Delta T_k^c = \begin{cases} T_{k.i} - T_k^{set}, \text{ if } T_k^{set} < T_{k.i}, \\ 0, \text{ otherwise.} \end{cases} \tag{2}$$

Stage 6. If all results are achieved for all executed current business processes, that is, the required "solution" Ps is obtained, all necessary states from the set of target states for all business processes are achieved, and then the method completes the work. Otherwise, proceed to Stage 5.

3. Results and Discussion

3.1. Results of the analysis of the process management method based on the case-based

Based on the previous presentation of the process management problem based on the case-based, the general model of the case is detailed. The main features of adaptive management of the set of end-to-end business processes of the enterprise are determined. This concerns the subject area in which the case can be applied (marketing, production, etc.), for which type of functional tasks, what is the complexity of their solution and what result can be obtained [21].

Given the characteristics of the case, the general model of its structure is expanded, with a tuple of the following form

$$M_p = \langle Sa, Zs, Ps, Gs \rangle, \tag{3}$$

where Sa – a restriction of the subject area regarding the application of the case; Zs – a description of the purpose of the business process and the content of the functional task, for the solution of which the case is developed; Ps – a description of the "solution" of the task Zs in the form of a sequence of works wf_i on the implementation of the end-to-end business process. The process of obtaining a "solution" as part of a case means the formation of a "controlling influence" that determines the order of access to resources of end-to-end business processes with

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restrictions on the time of their execution; Gs – the final result of solving the problem, which is achieved by successfully executing the last action of the end-to-end business process.

The description of the "solution" Ps combines a set of known ways Ps_i to solve the problem as part of the case $Ps_i = Ps_{1,j} \vee ... \vee Ps_{i,j} \vee ... \vee Ps_{I,J}$, each of which can be represented by a corresponding sequence of actions wf_i.

At the same time, the description of the solution of the problem Ps is presented as a set of processes P_i performed during the solution of the problem included in the case

$$s = \{P_i\}, \quad i = \overline{1,I}. \tag{4}$$

Each known solution process P_i can be represented as a sequence of events E_k, reflecting the execution of the corresponding sequence of actions that contributed to obtaining the desired result Gs:

$$\begin{aligned} &P_i = \langle E_k, \succ \rangle, \quad E_k = \{e_{k,i}\}, \\ &\forall e_{k,i} \exists e_{k,i+1} \neq e_{k,i} : e_{k,i} \succ e_{k,i+1}, \\ &E_k \subseteq E, \quad i = \overline{1,I-1}, \end{aligned} \tag{5}$$

where $\succ$ – the transition relation between events, which corresponds to the execution of an action in the process of solving the problem; E is the set of events for all the processes of solving the problem included in the case.

The obtained result of solving the problem without binding to the subject domain is expedient to be considered as a logical variable: if the result is achieved, then the value of Gs is true, if not, then the value of the constraints Sa is false. However, the successful solution of complex functional problems is usually associated with the achievement of one of the close (but different) results Gs_i, depending on the constraints of the subject domain.

In this case, provided that the result Gs is generalized, logically represented, it can be represented by the disjunction of local results

$$Gs \equiv \bigvee_i Gs_i. \tag{6}$$

Each of these results is obtained by implementing one of the possible options for the problem-solving process. That is, for a specific problem in the context of a case there may be several options for the "solution" of its solution $Ps_i \in Ps$. However, all options must ensure the achievement of the same result in the form of Gs (let's mean the logical representation of the result according to (5) for the existing case). Therefore, the formula for describing the "solution" Ps_i, which formalizes one of the possible processes for solving the problem, will be true in the case model at a point in time only if it ensures the receipt of one of the possible results Gs_i at one of the points in time in the future

$$M_p, t \models Ps_i \,|\, \forall t \exists Gs_i. \tag{7}$$

A logical representation of the subject area is used similarly. The description of the subject domain in the general case specifies a set of possible subsets of constraints for this problem $Sa \equiv \bigvee_i Sa_i$. The solution of the problem is considered acceptable if all the constraints of the subset $Sa \equiv \bigwedge_i Sa_i$ are taken into account.

Accordingly, the result of solving the problem Gs_i in the case model M_p will be true for the state of the model at a given time t only if the corresponding subset of the subject domain constraints Sa_i is fulfilled

$$M_p, t \models Gs_i \,|\, \forall t \exists Sa_i. \tag{8}$$

A generalized description of the problem is given through a set of goals Zs for launching a business process and its "solution" $Zs \equiv \bigwedge_l zs_l$. Then, for a correct description of the problem, it is necessary that each way of solving it Ps_i allows obtaining a true result Gz_i under the corresponding constraints of the subject area, that is, the connection between the problem, the way of solving it and the results without taking into account changes in the subject area has the form

$$\forall i \; Zs \to Ps_i \to Gs_i \,|\, Sa_i. \tag{9}$$

Then the condition for choosing a case for a problem Zs at the moment of time t when a subset of constraints Sa_i is valid is the presence of such a path to solve the problem Ps_i that would ensure the achievement of the result Gs_i when fulfilling the constraints on the path to solving the problem

$$L_p, t \models Zs \,|\, \exists Ps_i : \forall t \exists Gs_i \,|\, \forall t \exists Sa_i. \tag{10}$$

The given general model of the case can be detailed: determine in which subject area it can be applied (marketing, production, etc.), for which type of functional tasks, what is the complexity of their solution and what result can be obtained.

In order to use the case as an analogue, it is necessary to create a model of the current case Zs for the specific problem M_p^n being solved. Then, using the appropriate procedure, select from the database of cases the model of that analogue of the case M_p^a that is closest according to the results of the developed model of the current case.

The selection of a case-analogue M_p^a begins with the analysis of the model of the current case M_p^n, its purpose and the determination of those case-analogues that provide a solution to the problem in the subject area to which the current case belongs. The degree of their proximity (similarity) is primarily determined by the subject area Sa and the initial results Gs. An increase in the number of case-analogues leads to an increase in the probability of finding the most similar case-analogue for the current case, but at the same time it complicates the formation of the selection procedure, so the decision-maker must find an appropriate compromise. If the information system does not have a database of case-analogues, the implemented current case is stored in it.

3.2. Expanding the content of the current case description model

For a clearer understanding of the processes of case management of a group of end-to-end business processes, the content of the current case description model (10) was expanded and the process of adapting its model was detailed according to Stage 5. In this regard, the content of Stage 3 of fixing the model of the current case description of a group of end-to-end business processes was expanded.

According to the general case model (2), there is $Sa_i \to \left(z_i, r_{il}, t_{il}^h\right)$, $Ps_i \to \left(k_{il}, T_i^{set}, T_{k,i}\right)$, $Gs_i \to p_{i,L}$ – the final action of the sequence $wf_{i,j}$. Then the model of the current case description of a group of end-to-end business processes has the following form

$$M_p^n = \left(z_i, r_{il}, T_i^{set}, t_{il}^h, :_{il}, T_i^{fact}\right). \tag{11}$$

The content of the components of the case model:

– $Sa_i \to \left(z_i, r_{il}, t_{il}^h\right)$ – restrictions of the subject area that are associated with the features of the implementation of a group of orders z_i, which means that at each competitive point there may be a different number of business processes required to execute resources r_{il}, as well as the normative execution time of the l-th business process, the i-th order t_{il}^h;

– Zs, the goal of the business process execution, for the solution of which a case is developed, with each way of its solution Ps_i allowing to obtain a true result under the corresponding restrictions of the subject area (8);

– $Ps_i \to \left(k_{il}, T_i^{set}, T_{k,i}\right)$ – a description of the "solution" of the problem in the form of established priorities κ_{il} of access to resources by end-to-end business processes at each competitive point, taking into account the total actual $T_{k,i}$ and time of execution of the i-th order under the contract T_i^{set};

– *Gs*, the final result of the problem solution, which is achieved by the successful execution of the last *S*-th action from the wf_{ij} sequence

$$wf_{i,j} \models S^E \Leftrightarrow \exists ji : wf_{ij} \models p_{i,L}, \quad (12)$$

where $p_{i,L}$ – final action of the sequence wf_{ij}; the symbol |= determines the truth of the formula on the trajectory wf_{ij}.

To detail the process of adapting the current case model (10) according to Stage 5 of the considered method, steps have been added, which are considered as a sequence of the following actions:

Step 1. Calculation of the duration of execution of actions of each order t_{ij}^{i}, in *p*-th competitive points in the form of the sum of the waiting time $t_{ij}^{p\,wait}$ and the normative execution time of the action t_{ij}^{h}.

Step 2. Calculation of the remaining time $t_{ij}^{p\,left}$, execution of each business process by subtracting from the execution time of the order T_i^{set} under the contract the current execution time $t_{ij}^{p\,work}$ of the order to the corresponding competitive point $t_{ij}^{p\,left} = T_i^{set} - t_{ij}^{p\,work}$.

Step 3. Calculation of the total remaining time, execution of all orders in the corresponding order in each *p*-th competitive point $T_j^p = \sum_{i=1}^{N} t_{ij}^{p\,left}$.

Step 4. Setting the order launch orders κ_{il} in the *p*-th competitive point, according to the criterion of the largest total remaining time T_j^p.

Step 5. Calculation of the deviation of the largest value of the remaining total time T_j^p from the current $T_{k,i}$ for all orders at the *p*-th competitive point.

Step 6. Checking for negative values of the remaining total time T_j^p, executing business processes at the last *p*-th competitive point.

Step 7. If there are negative values of the remaining total time T_j^p, adjusting the sequence of order launch orders κ_{il}, the decision-maker is carried out by raising the order of execution of the corresponding order κ_{il} only one level up to minimize the risk of an incorrect decision after fixation at the 1st competitive point.

Step 8. Calculation of the value of the remaining total time T_j^p and checking for negative values T_j^p at the last competitive point, and if they are present, repeating Step 7.

The adjusted model of the current case is used to manage a group of end-to-end business processes, with its subsequent storage in the database of similar cases.

Unlike the existing one, the improved method of case management allows to obtain an optimal "solution" for setting the priorities of launching a group of business processes at each competitive point in accordance with the delays in their access to common resources. This allows to increase the efficiency of using enterprise resources by minimizing the total waiting time of each of these resources and reducing the deviation of the calculated term of business processes from the planned one.

3.3. Experimental verification of the results of improving the method of case management of a set of end-to-end business processes

Experimental verification of the results of improving the method was carried out when obtaining a "decision" Ps_i on setting priorities for launching a group of end-to-end business processes, implemented by Steps 1–8 of Stage 5 of the improved method, using the example of a group of 3 end-to-end business processes competing for common resources, with seven competitive points.

At the same time, for each order at each competitive point, the start and end times of the order execution are recorded, the normative time for the execution of the business process action is entered. Then the waiting time for its access to resources and the remaining time for the execution of each business process are calculated.

According to the content of Step 1, to calculate the duration of the execution of the actions of each order t_{ij}^{i}, in $p - x$ competitive points, the value of the normative time t_{ij}^{h}, is taken from the technological maps and the sum of the waiting times $t_{ij}^{p\,wait}$ is calculated. In addition, the total actual execution time $T_{k,i}$ is determined according to the corresponding business process launch orders.

To obtain such parameters of the current case, a database has been developed.

The database includes the following basic tables:

– *BPs* – a set of business processes as management objects;
– *BPGroup* – groups of business processes that are executed simultaneously;
– *Events* – a set of events that occur during the implementation of business processes and record the execution of the corresponding actions of business processes;
– *Resources* – a set of resources used when performing process actions.

The process of obtaining such parameters using this database schema is carried out as follows. The "Order No." parameter is formed in the "name BP" field of the "BP" table. The "BP" table is linked to the "owner" table one-to-many to form the process owner in the "name owner" field. Similarly, the "BP" table is linked to the "Processes" table many-to-many to form a set of processes for a specific order in the "Name processes" field.

The resource for executing the *l*-th business process is described by data fromvarious database tables: process name, equipment, workers, materials, circulation, format. This data is formed by a set of fields: the "Name processes" field of the "Processes" table, the field "name material" of the "Res material" table, the "name equipment" field of the "Res equipment" table, the "name labor" field of the "Res labor" table, the "printing" and "format" fields of the "Group_ BPs" table.

The database schema for obtaining the parameters of the current use case is presented in Fig. 1.

The execution time of the *i*-th order under the contract T_i^{set} is set in the "limitation time" field of the "Group_ BPs" table. The normative execution time of the *l*-th business process t_{il}^{h} is located in the calculated "calculation time pr" field of the "event" table. This field is calculated by the product of data from the "printing" field of the "Group_ BPs" table and the field "norm time" of the "Res equipment" table. Similarly, the waiting time (waiting for full execution) of resources for the execution of the *l*-th business process of the *i*-th order t_{il}^{wt} is located in the calculated "time wait" field of the "Group_ BPs" table. The remaining time for the execution of the *l*-th business process of the corresponding *i*-th order t_{il}^{left} is located in the calculated "left time" field of the "Group_ BPs" table. The actual execution time of the entire *i*-th order is located in the calculated "sum fact" field of the "Group_ BPs" table.

A software module has been developed to prioritize the options for launching each business process at all competitive points, using such a database. It supports the decision-maker actions in determining the best sequence of order execution orders at competitive points based on a specific situation of finding the necessary "solution".

The structure of the software module includes the following main blocks:

– research and adjustment of the decision-maker sequence of orders in the routes;
– calculation of business process priorities;
– solving tasks at the first stage, taking into account the maximum remaining time;
– solving tasks at the second stage of sequential order change at one competitive point;
– solving tasks at the third stage of sequential order change at two competitive points;
– solving tasks at the fourth stage of sequential order change at three competitive points;
– interface for displaying solution options;
– database of current cases;
– database of similar cases.

The module used the Visual Basic for Applications (VBA) programming language to automate the process of performing actions related to the calculations of orders at competitive points. Using (VBA), various software macros were developed, the texts of which are associated with the assigned corresponding buttons (Fig. 2).

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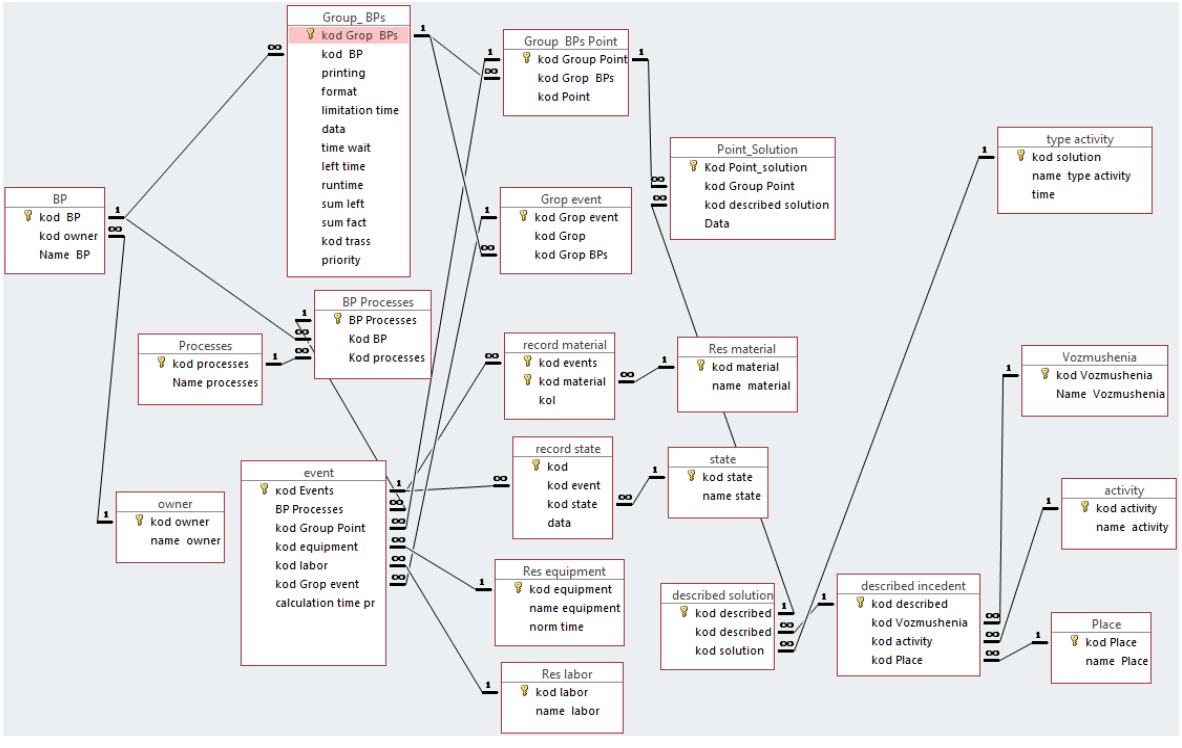

Fig. 1. Database schema for obtaining parameters of the current case

```
(General)                                                    Макрос2_2

Sub Макрос2_2()
'
' Макрос2_2 Макрос
' Макрос записан 21.01.2019 (user)
ActiveCell.FormulaR1C1 = "=RC[-3]"
    Range("R87:S87").Select
    Selection.Copy
    Range("U87:V87").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False
    Application.CutCopyMode = False
    ActiveCell.FormulaR1C1 = ""
    Range("S21").Select
    ActiveCell.FormulaR1C1 = "=R[66]C[3]"
    Range("O89").Select

End Sub
```

Fig. 2. Text of the macro associated with the "Cont.2.2" button

When the corresponding button is pressed, a certain macro is launched, which launches the program to execute the corresponding order and fixes the order of their launch at the selected competitive point. The software module used some buttons to which not one, but several nested macros were assigned. The largest number of nested macros in the amount of 252 was assigned to the "Fix button". Such buttons provide restarting of the software tool with subsequent saving of the previously obtained calculation result. To automatically calculate various actions by the software tool to determine optimal orders, corresponding macro expressions have been developed for their installation, movement, calculation using various parameters when fulfilling the imposed conditions and restrictions.

To view the data by decision-maker for any option, as well as information about the options for the installed orders with the time remaining at the corresponding competitive points, it is necessary to click on the corresponding group of buttons. If the proposed "solution", in the form of a changed sequence of orders, suits the decision-maker, then it implements such a sequence as a controlling "solution", with its fixation and storage with a corresponding description in the database of cases-analogs.

In the case of a negative "solution", the adjustment of the sequence of orders for starting the order is carried out by the decision-maker by raising the order of execution of the corresponding order only one level up to minimize the risk of an incorrect decision after fixation at the corresponding competitive point.

An example of obtaining optimal sequences of orders for passing all orders (books, brochures and magazines) of competitive points is presented in Fig. 3.

Analysis of the results shows that the best sequence of orders for launching these end-to-end business processes at the corresponding control points is a sequence with a total remaining time equal to 20 (0 for a book, 4 for a brochure and 16 for a magazine). This means that all orders will be fulfilled, because there are no negative values of the remaining time for each order. This confirms the effectiveness of the developed improved method of case management of a set of business processes, according to the indicator of the fulfillment of all orders within the established time.

In fact, these data reflect the content of the "solution" options for passing these orders through all 7 competitive points. After the implementation of the received "solution", it, together with the description of the current case, is stored in the case database. This allows it to be used to manage another group of orders, which will significantly reduce the cost of developing an adapted model for a new case.

Kod BP	Kod processes	Priority	Name BP	Time process	Time general	Time waiting	Time end	Time left
1	1	1	book	4	120	0	4	116
1	2	3	book	10	120	13	23	93
1	3	1	book	10	120	0	10	83
1	5	3	book	14	120	17	31	52
1	6	3	book	12	120	10	22	30
1	7	2	book	9	120	5	14	16
1	8	2	book	12	120	4	16	0
Total: book							120	**0**
2	1	2	brochure	8	110	4	12	98
2	2	2	brochure	8	110	5	13	85
2	3	3	brochure	8	110	16	24	61
2	5	2	brochure	10	110	7	17	44
2	6	2	brochure	6	110	4	10	34
2	7	3	brochure	12	110	14	26	8
2	8	1	brochure	4	110	0	4	4
Total: brochure							106	**4**
5	1	3	magazine	10	100	12	22	78
5	2	1	magazine	5	100	0	5	73
5	3	2	magazine	6	100	10	16	57
5	5	1	magazine	7	100	0	7	50
5	6	1	magazine	4	100	0	4	46
5	7	1	magazine	5	100	0	5	41
5	8	3	magazine	9	100	16	25	16
Totall: magazine							84	**16**

Fig. 3. The best sequence of orders for passing competitive points

3.4. Discussion of the research results

The study considers the case-based reasoning to managing a group of end-to-end business processes, aimed at using existing experience, in particular, when implementing process management at new enterprises, solving new tasks that have implemented analogues. Implementation of process management based on the case-based involves searching for and adapting a case, its application and subsequent storage. In this case, when implementing the case-based, the procedure for adapting the case is performed even before the start of managing the corresponding process. This makes it possible to adapt the management process and change the sequence of processes during execution, especially when accessing common resources. Modern methods and tools for intelligent process analysis (Process Mining) provide the ability to build case solutions to problems in the form of models of the corresponding business processes. Models of business process cases determine the sequence of solving the problem, but do not take into account the interaction of processes and the possibility of their use of common resources, which can lead to significant delays in the execution of business processes [3]. In this case, there is no possibility within the framework of the case-based to solve the problem of managing a set of processes under the condition of changing the composition of the elements of this set. Therefore, the issue of adaptive management of a set of processes as elements of cases requires further improvement.

There is a method of adaptive process management based on the case-based, which consists in adjusting the sequence of execution of a set of business processes in the enterprise during the change in the composition of this set: adding new processes, completing current ones, the appearance of "bottlenecks", etc. [21]. The method allows for the formalization of the formation of a description of the current case, behind which there is an analogue case and after its adaptation it is used as a controlling influence. At the same time, the necessary solution is found in the form of changing the priorities of access of business processes to each shared resource in order to minimize the waiting time of resources with restrictions on the execution time of each of these processes. The adjusted case-analog model is used to manage a group of end-to-end business processes, with its further use and storage in the case-analog database. The development and maintenance of such a solution model in the form of changing the priorities of business processes' access to each shared resource is a complex task.

A feature of the obtained results is a description of the content of the components of the case model with explanations of the process of their implementation when using the improved method, which is important for its practical implementation (10). Another feature of the obtained results is the detailing of the process of adapting the current case model at Stage 5 of the improved method in favor of describing the eight steps of operational adjustment of determining the priorities of access of competing business processes to resources, taking into account the limitations on the time of their execution. The implementation of the improved method confirmed that all orders will be executed, because there are no negative values of the time remaining for each order (Fig. 3), This confirms the effectiveness of improving the method of case management of a set of business processes, according to the indicator of the execution of all orders within the established time.

The obtained research results in the form of the best sequences of the order of passage of all orders should be recognized as important for further theoretical and applied research in the field of end-to-end business process management.

The limitations are the possibilities of updating the database (Fig. 1) and the properties of the software module with the developed software macros (Fig. 2).

The main further directions of development of this research are:

– conducting research on the development of information technology for establishing access priorities to common resources of competing business processes at the relevant competitive points, which would ensure their implementation within the terms established by the contracts;

– conducting experimental verification of the proposed improved method when changing the composition of business processes at competitive points.

4. Conclusions

1. The main features of adaptive management of a set of end-to-end business processes of an enterprise are distinguished, which are associated with changes in the sequence of processes during execution, especially when accessing common resources. At the same time, business process case models determine the sequence of solving the problem, but do not take into account the interaction of processes and the possibility of their use of common resources, which can lead to significant delays in the execution of business processes. At the same time, there is no possibility within the framework of the case-based to solve the problem of managing a set of processes under the condition of changing the composition of the elements of this set. Therefore, the issue of adaptive management of a set of processes as elements of cases requires further improvement.

2. The content of the current case description model has been expanded and the adaptation process has been detailed. The content of the components of the case model includes restrictions on the subject area, which are associated with the specifics of the implementation of a group of orders, a description of the "solution" of the problem in the form of established priorities for access to resources by end-to-end business processes, and the final result of solving the problem. The process of adapting the current case model according to Stage 5 of the existing method is detailed by adding eight steps of operational adjustment of determining the priorities for access of competing business processes to resources, taking into account the restrictions on the time of their execution. Improving the method allows to obtain an optimal "solution" for setting the priorities for launching a group of business processes at each competitive point in accordance with the delays in their access to common resources. Determining the order of passage of all orders is performed taking into account the restrictions on the terms of execution of each of the business processes, which allows to improve the process of managing orders at the enterprise. An indicator of increasing the efficiency of managing a set of business processes is their 100% execution within the terms established by the contract.

3. Experimental verification of the application of the developed improved case management method is considered on the example of the process of obtaining a "solution" on setting priorities for launching business processes on the example of a group of 3 end-to-end business processes competing for common resources with seven competitive points. An example of obtaining optimal sequences of orders for passing all orders (books,

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brochures and magazines) of competitive points in the form of the best sequence of their launch orders at the corresponding control points is considered. After obtaining the best results, this "solution", together with a description of the current case, is stored in the case database and this will allow it to be used to manage another group of orders, which will significantly reduce the costs of developing an adapted model of a new case. A software module has been developed to prioritize options for launching each business process, using such a database, at all competitive points depending on the remaining time, their mandatory execution in accordance with the terms specified in the relevant contracts. The module supports the decision-maker in determining the best sequence of order execution orders at competitive points based on a specific situation of finding the necessary "solution".

The determination of the order of passage of all orders is performed taking into account the limitations on the terms of execution of each of the business processes, which allows improving the process of order management at the enterprise. An indicator of increasing the efficiency of managing a set of business processes is their 100% execution within the terms specified in the contract.

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Conflict of interest

The authors declare that they have no conflict of interest regarding this research, including financial, personal, authorship or other, which could affect the research and its results presented in this article.

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Data availability

The manuscript has no related data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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