CHAPTER 2

Cost management of an information system IT project in the conditions of incomplete information about its elements

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Abstract

The object of the study is the process of managing IT project decisions.

During the study, the problem of modeling losses during the design of a description of an information system (IS) element in conditions of incompleteness or lack of complete information about this element was solved. Research in this area is devoted to the development and improvement of models for making design decisions in conditions of complete certainty, risk and partial uncertainty. The formation and making decisions on managing IT projects in conditions of partial uncertainty remain almost unexplored.

It is proposed to use for the IT industry a cause-and-effect scheme for the formation of losses in industrial production due to the lack of information. According to this scheme, the consequences of the situation of the lack of information about the description of the IS element and the loss models that characterize these consequences were analyzed. The proposed scheme was adapted to the features of the design and implementation processes of IS elements. Detailed loss models were developed for the four main consequences of the situation of incompleteness or lack of information about the description of the IS element.

Experimental verification of the obtained results was carried out on the basis of the IT project for the creation of the "Electronic Compulsory Motor Third Party Liability Insurance Policy" service. The consequences of identifying an incomplete description of this service during the design process were considered. Two options for replacing the incomplete description of this service were proposed: developing the service "from scratch"; using the description of the "Online Store" module

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functions selected from the IT project backlog. For the first option, the estimate of possible losses is \$123300.12. For the second option, the estimate of possible losses is \$50000.

During the analysis of the obtained results, it was noted that the obtained estimates characterize losses only on the IT project iteration that is planned. To increase the accuracy of the assessment of losses from eliminating the situation of lack of information about the description of the IS element, further research was deemed necessary. It was also deemed appropriate to conduct prospective research on the creation of IS and information technologies to support the assessment and decision-making of the management of an IT company and its IT projects in a time regime close to real time.

Keywords

IT project, description of a system element, incomplete information, cause-and-effect scheme, loss model, information system function.

2.1 Introduction

The decision management process is one of the technical project management processes [1]. The processes in this group are used to establish and deploy plans, execute plans, assess actual achievement and progress against plans, and manage project performance. The scope of these processes is the technical management of a project or its products for inclusion in a system. Therefore, individual technical management processes can be applied at any time in the life cycle and at any level in the project hierarchy, as required by plans or due to unforeseen events [1].

The purpose of the decision management process is defined in [1] as providing a structured, analytical framework for objectively identifying, characterizing, and evaluating multiple solution alternatives at any point in the system life cycle and selecting the most advantageous course of action. This process is used to solve technical or design problems and respond to solution requests that arise during the system life cycle, and to determine the alternative that provides the best results in a given situation.

However, the problems of decision-making in project management are far from being completely solved. Thus, in [2] the scope of project execution "Uncertainty" is defined, which covers operations and functions related to risk and uncertainty. The allocation of this scope confirms the understanding of the importance of using models and methods for solving decision-making problems under risk and partial uncertainty in project management systems. But when it comes to specific recommendations for the implementation of such models and methods, in [2] only the following options for responding to uncertainty are proposed:

– collecting additional information;
– preparing for several final results;
– design based on a set;
– developing resilience.

All of these options require additional time during project management, which is undesirable, especially for such a type of project as IT projects. The reasons for such undesirability lie mainly in the possibility of significant time losses as a result of exceeding the deadlines for the implementation of the IT project. The options for responding to uncertainty specified in [2] leave open the question of the possibility of using already known models and decision-making methods in IT project management. It should be recognized that such models and methods were mainly developed for other types of management than IT project management. Therefore, there is a need to conduct scientific and applied research in the field of developing new and using existing models and decision-making methods under uncertainty to solve IT project management problems.

2.2 Analysis of current research in the field of IT project decision management

Modern analysis of the application of traditional project management models and methods recognizes as the main challenge and the main direction of research in this field the complexity of project processes, due to which they do not meet the initial deadlines, cost, quality and business goals [3]. Based on this, in [3] the following main difficulties in project management are highlighted: delays in the project implementation schedule; lack of clearly defined goals and support from management/company; changes in scope; insufficient resources; poor risk management and measurement of project effectiveness; lack of communication between project participants. All these difficulties lead to solving project management problems under conditions of risk or partial uncertainty. Such conditions, in turn, necessitate the use of formal models and decision-making methods in the decision management process discussed above. The importance of using decision-making models and methods based on a scientific approach in project management is also confirmed by experimental studies. Thus, in [4], data from two randomized controlled studies involving 382 entrepreneurs were analyzed, who were divided into two groups:

– a group of "scientific" entrepreneurs, who were trained in a scientific approach to decision-making regarding project selection before the experiments began;

– a group of "ordinary" entrepreneurs.

The results of the analysis presented in [4] allow to draw the following conclusions:

– the increased probability of project termination by "scientific" entrepreneurs is associated with greater accuracy in determining the cost of the project;

– "scientific" entrepreneurs are faster to adjust their expectations regarding the cost of the project downwards before making a decision to terminate the project;

– "scientific" entrepreneurs generate a greater number of new ideas, and a greater proportion of their projects end with the opening of a business;

– in the long term (up to five years), the initial difference in termination rates between "scientific" and "ordinary" entrepreneurs is equalized;

– the control group, which consisted of "regular" entrepreneurs, shows a higher rate of project abandonment in the long term (up to five years).

These findings generally support the idea that "scientific" entrepreneurs are not overly critical in their evaluation of their projects; rather, by abandoning projects with lower potential earlier, they can free up resources to reallocate elsewhere [4].

It should be recognized that in general, scientific methods and decision-making models are used in the management of a wide variety of projects. Thus, according to the results of the study [5], it is proposed that outsourcing decisions, including the choice of outsourcing service and contractor, be made by an expert group. [5] also considers constant monitoring and control of the quality of external units and the satisfaction of stakeholders to be important. [6] proposes to use a resource optimization model based on a genetic algorithm to solve the problem of resource optimization in the management of research projects. [7] proposes to use object information modeling technology to visually display the cost of the project, generalize and integrate various costs and, thus, obtain a total budget for the cost of the project to find optimization solutions in order to facilitate analysis and decision-making by project managers and relevant personnel. However, all the studies considered are based on the assumption that decision-making in project management is carried out under conditions of certainty.

Issues of decision support in project management under risk and uncertainty are also highlighted in modern research. Thus, the main structural components, elements and functions of an intelligent software system are described in [8], which is a tool for supporting management decisions in the implementation of practical projects in the field of economic management. This system is built on the principles of the methodology for optimizing adaptive project management using network economic and mathematical modeling and the feedback principle. The use of this methodology allows taking into account the incompleteness of information associated with the failure or delay of specific project operations.

In [9], a review of solutions for computer-aided decision support for offshore software outsourcing in the global context of the development of such systems is provided. In particular, in [9] ten main key factors related to the decision-making process in the IT industry were identified, namely: human communication, cost reduction, organizational and professional maturity, project management methods, IT infrastructure support, language restrictions, knowledge-based support, changes in requirements, legal issues and cultural diversity. However, the data obtained in [9] show that the software industry lacks effective and efficient decision-making models that take into account the specifics of the IT industry and, in particular, the features of management in IT projects. The conclusion about the lack of application of effective and efficient models of decision-making and decision-making in IT project management is also confirmed by the results of other studies. Thus, in [10] an approach to decision analysis is proposed, which allows for the implementation of structured, reproducible and group execution of relevant procedures using a decision support system. However, this approach, as shown in [10], has only a methodological basis. In [11], a study was conducted to support decision-making on the implementation of test automation in the context of Agile-based Software Development.

In total, the study identified twenty-one factors that significantly affect test automation in the specified context. But the final result of applying the identified factors in [11] is only a conceptual model designed to help managers practicing Agile make decisions on the implementation of test automation in the specified context.

The results of the analysis allow to conclude that it is appropriate to conduct scientific and applied research in the field of developing new and improving existing formal models and decision-making methods for IT project management. These studies, taking into account the results obtained in [4], are proposed to be based on the following assumptions:

– the greatest effect from the application of these models and methods should be expected when making decisions on current and operational management of work at the early stages of the project;

– it is desirable to use such models and decision-making methods from various aspects of project management that would allow to assess the impact of the studied alternatives of the decision being formed and adopted on the overall assessment of the project cost and, accordingly, on the estimates of the costs of performing the work of this project.

These assumptions made it possible to determine that the purpose of this study is to develop loss models when designing a description of the elements of the enterprise management information system (IS) in conditions of incompleteness or lack of complete information about these elements. The use of these models will allow formalizing the procedure for choosing a rational option for using personnel and IT infrastructure of an IT company during the design or implementation of IS elements, the descriptions of which are characterized by incomplete information.

To achieve this aim, it is proposed to solve the following research objectives:

– adapt the situational-consequential scheme of production losses due to lack of information to the features of the design processes of IS elements;

– develop and implement detailed loss models for the main consequences of production losses and decision-making on managing iterations of the implementation of the IT project of creating IS;

– perform experimental verification of the results obtained.

2.3 Research models

To determine the mechanism of loss formation during the design and implementation of IS elements, it is proposed to apply the existing causal scheme of loss formation in production due to the lack of information (**Fig. 2.1**) [12]. It should be noted that causal schemes are considered by some modern researchers as one of the means of overcoming uncertainty in project management [13].

In **Fig. 2.1**, the following designations are adopted: Ex_1 – "Replacing missing information with other, for example, scattered or indirect" consequence; Ex_2 – "Concentration of production resources on performing work not for their direct purpose" consequence; Ex_3 – "Transferring production resources to performing work that corresponds to their direct purpose" consequence; Ex_4 – "Refusal to use resources due to the lack of information for making management decisions" consequence; Ex_5 – "Any measures to maintain the required duration of the production cycle are not taken" consequence; Ex_6 – "Intensification of the production process after the elimination of uncertainty" consequence; P_1–P_8 and P'_9–P'_{13} – losses characterizing the corresponding consequences; P_{sum} – total losses of the consequence Ex_1; W_1–W_3 – penalties for failure to complete the planned work on time. A detailed description of these elements is given in [12].

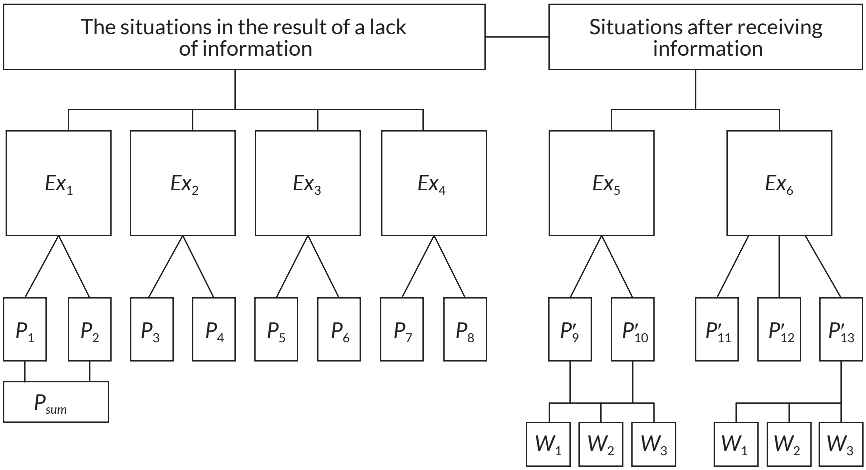

Fig. 2.1 Cause-and-effect scheme of production losses due to lack of information

The occurrence of a situation where there is no information can lead to one of the consequences Ex_1, Ex_2, Ex_1 and Ex_4. The consequence Ex_1 attracts the most attention among them, because it allows replacing the description of an IS element for which complete information is missing with reusable descriptions of other IS elements being designed or other IS. The loss models P_1 and P_2, which characterize the consequence Ex_1, have the form [12]:

$$P_1 = S_{add} R(H) k, \tag{2.1}$$

$$P_2 = \Delta S R(H) k, \tag{2.2}$$

where P_1 – losses from the absence of information in the event of the need for further processing with replacement information; S_{add} – the average cost of additional processing of replacement information; $R(H)$ – the average number of occurrences of situations of absence of information for the analyzed period of time T with a certain composition of information $H = \{h_1, h_2, \ldots, h_n\}$; k – the coefficient of quality of management decision-making; P_2 – losses from the absence of information in the presence of a difference in the cost of information being replaced and information being replaced; ΔS – the average difference in the cost of information being replaced and information being replaced. In some cases, as shown in the scheme (**Fig. 2.1**), these losses are summed up.

According to the result of Ex_2, production resources are concentrated on performing work not for their direct purpose. For this case, the loss models P_3 and P_4, which characterize the consequence of Ex_2, have the form [12]

$$P_3 = \beta S_{res_{av}}^{t_{st}} \times l t_{indef}(H) R(H) k_1 \tag{2.3}$$

provided $t_{indef}(H) \geq t_c$;

$$P_4 = \beta S_{res_{av}}^{t_{st}} \times l t_c(H) R(H) k_1 \tag{2.4}$$

provided that $t_{indef}(H) < t_c$, where P_3, P_4 – losses from uncertainty of the situation due to the lack of management information when transferring resources to perform work not for their direct purpose; b – coefficient of losses on the cost of resources when they perform work not for their direct purpose; $S_{res_{av}}^{t_{st}}$ – average cost of a resource unit for a normalized period of time t_{st}; l – number of conditional units of resources; $t_{indef}(H)$ – average time of uncertainty of the situation with a certain information composition H; t_c – average cycle of performing a normalized unit of work; k_1 – coefficient of quality of work performance.

The consequence Ex_3 is characterized by the transfer of production resources to perform work that corresponds to their direct purpose, which is possible in the case when the production process has additional components that ensure the employment of resources for a time not less than the time of uncertainty of the situation. If, to eliminate forced downtime of resources, the work is selected from a random set of unfinished work (if such is always available) and at the same time the creation of any special reserve is not required, then the losses can be calculated by the formula [12]

$$P_5 = \left(\frac{R(H) t S_{av.nc.w} t_{indef}(H)}{T t_c} + W_{sum} \right) - S_{unfin.w}, \tag{2.5}$$

where t – the time period under consideration; $S_{av.nc.w}$ – the average cost of an unperformed unit of work as a result of transferring resources; W_{sum} – the total value of penalties for failure to complete scheduled work on time as a result of transferring resources to reserve work; $S_{unfin.w}$ – the cost of completing unfinished work.

If a special reserve of work is created, then the losses are [12]

$$P_6 = \left(\frac{R(H) t S_{av.nc.w} t_{indef}(H)}{T t_c} + W_{sum} + S_{reserve} \right) - S_{compl.w.reserve}, \tag{2.6}$$

where $S_{reserve}$ – the cost of creating a special reserve of work; $S_{compl.w.reserve}$ – the cost of the completed reserve of work.

Consequence Ex_4 is a situation when, due to the lack of information for making management decisions, resources are not used. Losses in this case are proposed to be estimated in [12] as follows

$$P_7 = S_{res_{av}}^{t_{st}} \times lt_{indef}(H)R(H) \quad (2.7)$$

provided $t_{indef}(H) \geq t_c$;

$$P_8 = S_{res_{av}}^{t_{st}} \times lt_c R(H) \quad (2.8)$$

provided $t_{indef}(H) < t_c$.

After receiving the information necessary for making management decision information, consequences Ex_5 and Ex_6 arise. They are the results of consequences Ex_2, Ex_3 and Ex_4. Let's define consequence Ex_5 as a consequence in which no measures are taken to maintain the required production cycle duration. Naturally, in [12] it is assumed in this case that t_c will increase by $t_{indef}(H)$ from the moment of time at which the cycle was interrupted.

For the consequence Ex_5, if the lack of information does not lead to an increase in the volume of work in progress, the losses are estimated as follows [12]

$$P_9' = W_{sum}. \quad (2.9)$$

In the case of an increase in the volume of work in progress, losses are determined as follows [12]

$$P_{10}' = \frac{S_{unfin_{av}} t_{indef}(h)R(H)}{T} + W_{sum}, \quad (2.10)$$

where $S_{unfin_{av}}$ – the average cost of work in progress.

The losses associated with the penalty for the consequence Ex_5, in the case of an increase in t_c, may have different values. If the increase in t_c does not lead to an increase in the critical period, $W_1 = 0$; if t_c increases and exceeds the critical period by an amount not greater than that specified in the relevant regulatory documents, then

$$W_2 = \alpha S_{unfin_{av}}^{compl} R(H), \quad (2.11)$$

and in the case of an excess of t_c over the critical period by an amount greater than that specified in the standards,

$$W_3 = \alpha_1 S_{unfin_{av}}^{compl} R(H), \tag{2.12}$$

where α, α_1 – the corresponding penalty coefficients for the specified cases; $S_{unfin_{av}}^{compl}$ – the average total cost of work in progress.

The consequence Ex_6 is characterized by the fact that the production process after the elimination of uncertainty intensifies. If the increase in t_c due to the uncertainty of the situation can be eliminated without additional costs, for example, by reducing the inter-operational lag, the losses are zero ($P'_{11} = 0$). A possible option is when, in order to reduce t_c, the process is intensified by overtime use of resources [12].

Then, if $\Delta t \geq t_{indef}(H)$, losses $P'_{12} = \gamma S_{res_{av}}^{t_{st}} \times l t_{indef}(H) R(H)$, where γ – the coefficient that increases the cost of resources in the case of their use in overtime; Δt – the maximum possible reduction in the cycle duration. When [12]

$$P'_{13} = \gamma S_{res_{av}}^{t_{st}} \times l \Delta t R(H) + \frac{S_{unfin_{av}} R(H)(t_{indef}(H) - \Delta t)}{T} + W_{sum}. \tag{2.13}$$

The losses due to penalties when increasing t_c are determined by formulas (2.11), (2.12) [13].

The scheme considered in **Fig. 2.1** was developed for manufacturing enterprises and does not take into account the peculiarities of the processes of designing and implementing IS elements. In addition, the loss and penalty models (2.1)–(2.13) are not detailed, which makes their application in managing an IT project for creating or improving IS much more difficult.

2.4 Results of adapting the causal scheme of production losses to the features of the design processes of an information system element

In the course of adapting the causal scheme of production losses due to lack of information [12], it was decided to take into account the following features of the design and implementation processes of IS elements in an IT company:

– each specific IS corresponds to a separate IT project, which is performed by IT company employees within a predetermined time frame;

– an IT company can simultaneously perform several different IT projects;

– management of IS element development teams is carried out iteratively based on Agile IT project management methodologies;

– the description of each IS element being created is performed by one or more developers using a uniform structured template of this description H;

– in the process of forming descriptions of individual IS elements, developers strive to achieve the maximum possible reuse of descriptions of existing elements of similar IS;

– the content of the task backlog for the development team as a set of IS element descriptions and even the duration T of each iteration (sprint, etc.) are set at the beginning of execution;

– the content of the task backlog rarely changes during the iteration being performed.

Here and now, the developers of IS elements will be understood as IT service providers who are employees of an IT company that takes responsibility for creating IS according to the requirements of IT service consumers [14] during all relevant stages of the IS life cycle [1].

These features allowed to formulate the definition of the consequences highlighted in the scheme as follows:

– consequence Ex_1: "Replacement of missing information with information about a similar IS element that is reused";

– consequence Ex_2: "Concentration of IT company personnel and IT infrastructure elements on the design or development of other IS elements";

– consequence Ex_3: "Transfer of IT company personnel and IT infrastructure elements to the design or development of other elements of the same IS";

– consequence Ex_4: "Refusal to use the personnel and elements of the IT infrastructure of the IT company due to the lack of information about the IS elements";

– consequence Ex_5: "Failure to take any measures to maintain the required duration of the iteration T";

– consequence Ex_6: "Intensification of the processes of implementing the IT project of creating the IS after eliminating uncertainty".

Then the elements of the generalized loss formulas (2.1) and (2.2) are proposed to be interpreted as follows: P_1 – losses from the lack of information in the event of the need for additional processing with information from the description of the reused IS element; S_{add} – the average cost of additional processing of information, which is replaced, from the reused description of the IS element; $R(H)$ – the average number of occurrences of situations of lack of information for the period of time T under consideration, with a priori established template of the description of the IS element $H = \{h_1, h_2,..., h_n\}$; k – the coefficient of quality of management decision-making;

P_2 – loss from the absence of information in the presence of a difference in the value of the information being replaced and the information being replaced from the reused description of the IS element; ΔS – average difference in the value of the information being replaced and the information being replaced from the reused description of the IS element.

The elements of the generalized loss formulas (2.3) and (2.4) are proposed to be interpreted as follows: P_3, P_4 – losses from the lack of management information when transferring personnel and IT infrastructure elements of an IT company to the design or development of other IS elements; b – coefficient of losses on the cost of personnel and IT infrastructure elements of an IT company when they are used during the design or development of other IS elements; $S_{res_{av}}^{t_{st}}$ – average cost of a unit of personnel and IT infrastructure elements of an IT company for a normalized period of time t_{st}; l – number of conditional units of resources (personnel and IT infrastructure elements) of an IT company that are used during the design or development of other IS elements; $t_{indef}(H)$ – average duration of the uncertainty of the description of an IS element with a priori established template of this description $H = \{h_1, h_2,..., h_n\}$; t_c – average duration of one iteration of the IT project work on the design and implementation of an IS element, $t_c = T$.

The elements of the generalized loss formulas (2.5) and (2.6) are proposed to be interpreted as follows: P_5 – losses from the transfer of personnel and IT infrastructure elements of the IT company to perform work on the design or development of IS elements in the case when this work is selected from a random set of unfinished work (if such is always available) and the creation of any special reserve is not required; P_6 – losses from the transfer of personnel and IT infrastructure elements of the IT company to perform work on the design or development of IS elements in the case when this work is selected from a created special reserve of work; $S_{av.nc.w}$ – the average cost of a unit of work not performed as a result of the transfer of personnel and IT infrastructure elements of the IT company; W_{sum} – the total value of penalties for failure to perform scheduled work on time as a result of the transfer of personnel and IT infrastructure elements of the IT company to reserve work.

The elements of the generalized loss formulas (2.7) and (2.8) are proposed to be interpreted as follows: P_7, P_8 – losses from non-use of personnel and IT infrastructure elements of the IT company due to the lack of information for making management decisions.

Similarly, the semantics of costs P'_9 and P'_{10} was clarified for the consequence Ex_5 and costs P'_{11}, P'_{12} and P'_{13}, and for the consequence Ex_6. However, this clarification slightly changed the descriptions and interpretations of these costs.

2.5 Results of developing detailed models of losses from lack of information

The results of adapting the situational-consequence scheme of loss generation to the features of the design processes of IS elements, considered in **Section 2.4**, leave open the question of a detailed method of calculating these losses. Therefore, to apply the proposed mechanism of loss generation during the design and implementation of IS elements, it is necessary to develop detailed loss models that would allow obtaining quantitative estimates of losses for the consequences Ex_1–Ex_6.

In the process of formulating a detailed description of the loss models (2.1) and (2.2), it was established that the main problem lies in clarifying the formal description of the parameters S_{add} and ΔS. Based on the results of developing parametric models for estimating labor costs (the modern term is efforts) for the implementation of the COCOMO II IT project [15], the following assumptions were formulated:

– Assumption 1: at different stages of the IS creation life cycle, different models are used to estimate efforts;

– Assumption 2: the need for personnel to perform the estimated work during an iteration with a duration of T can be determined by dividing the obtained effort estimate by the value of the parameter T;

– Assumption 3: the costs of operating IT infrastructure elements in the most common conditions of an IT company's activity can be considered constant and evenly distributed over iterations with a duration of T.

These assumptions were proposed to be used as the basis for developing detailed loss models P_1 and P_2.

In the case of using the P_1 (2.1) loss model to estimate losses in the case of consequence Ex_1, the most difficult thing is to determine the value of the parameter S_{add}. Taking into account the above-mentioned features of the design and implementation processes of IS elements, as well as the results of adapting the cause-and-effect scheme of losses in production due to the lack of information, this parameter is proposed to be described as follows

$$S_{add} = \sum_{z=1}^{R(H)} \left(\sum_{i=1}^{m} k_{zi} q_{zi}(T) St_{zi}(T) + \sum_{j=1}^{n} k_{zj} q_{zj}(T) CI_{zj}(T) \right), \tag{2.14}$$

where k_{zi} – the normative value of the cost of wages of a developer who is engaged in the process of creating the z-th IS element in the time period T in the i-th position; $q_{zi}(T)$ – the number of developers who are engaged in the process of creating the z-th IS element in the time period T in the i-th position; $St_{zi}(T)$ – the operator that establishes the fact that developers are in the process of creating the z-th IS element in the time period T in the i-th position; k_{zj} – the normative value of the cost of operating the j-th IT infrastructure element in the process of creating the z-th IS element in the time period T; $q_{zj}(T)$ – the number of j-th IT infrastructure elements operated in the process of creating the z-th IS element in the time period T; $CI_{zj}(T)$ – an operator that establishes the fact of operation of the j-th IT infrastructure elements that are operated in the process of creating the z-th IS element in the time period T.

Taking into account Assumption 3, expression (2.14) can be written in a simplified form

$$S_{add} = \sum_{z=1}^{R(H)} \sum_{i=1}^{m} k_{zi} q_{zi}(T) St_{zi}(T) + \sum_{z=1}^{R(H)} C_{CI}(z), \tag{2.15}$$

where $C_{CI}(z)$ – the constant value of the costs of operating IT infrastructure elements in the process of creating the z-th IS element in the time period T.

Thus, it is necessary to determine the number of developers $q_{zj}(T)$, which is required to eliminate the situation that arose as a result of the lack of complete information about the description of the IS element in the IT project iteration of duration T, which is planned or implemented. Based on the COCOMO model, this parameter is proposed to be calculated in the following way

$$q_{zi}(T) = P_z / T, \tag{2.16}$$

where P_z – the effort to perform additional processing of the replacing information.

When using the P_2 (2.2) loss model to estimate losses in the case of the consequence Ex_1, the most difficult thing is to determine the value of ΔS. To do this, it is first necessary to establish the peculiarity of the difference in the values of the information being replaced and the information being replaced. This peculiarity arises as a result of using the mechanism for reusing descriptions of previously developed IS elements. According to this mechanism, reuse of the description of an IS element is possible in one of the following cases:

– case I: the description was developed and implemented during one of the previous iterations;

– case II: the description is planned to be developed and implemented during the same iteration as the replaced description of the IS element, but one or more days earlier.

In case I, the value of the information value S_{repm}, which is replaced, is known to the developers for this element quite accurately from the reports on the progress of the previous iterations. In case II, the developers can only operate with an estimate of the value of the information value $\hat{S}_{repm}$, which is replaced. This estimate, by analogy with (2.14) and (2.15), is proposed to be defined as follows:

$$\hat{S}_{repm} = \sum_{i=1}^{m} k_{ri} q_{ri}(T) St_{ri}(T) + \sum_{j=1}^{n} k_{rj} q_{rj}(T) CI_{rj}(T), \tag{2.17}$$

$$\hat{S}_{repm} = \sum_{i=1}^{m} k_{ri} q_{ri}(T) St_{ri}(T) + C_{CI}(z), \tag{2.18}$$

where r – the IS element, the description of which will be developed and reused in the planned iteration. The value of the quantity q_{ri} is set by a formula similar to (2.16).

As for the value of the information being replaced, developers can also operate only with its estimate $\hat{S}_{repd}$. The value of this estimate is proposed to be calculated, by analogy with (2.17) and (2.18), as follows:

$$\hat{S}_{repd} = \sum_{i=1}^{m} k_{di} q_{di}(T) St_{di}(T) + \sum_{j=1}^{n} k_{dj} q_{dj}(T) CI_{dj}(T), \tag{2.19}$$

$$\hat{S}_{repd} = \sum_{i=1}^{m} k_{di} q_{di}(T) St_{di}(T) + C_{CI}(d), \tag{2.20}$$

where d – the IS element, the description of which is incomplete or missing at the time of planning the iteration.

Then the value in (2.2) is proposed to be determined as follows

$$\Delta S = \sum_{r=1}^{R(H)} S'_{repm,r} - \sum_{d=1}^{R(H)} \hat{S}_{repd,d}\,, \tag{2.21}$$

where

$$S'_{repm,r} = \begin{cases} S_{repm,r} & \text{if (I)}, \\ \hat{S}_{repm,r} & \text{if (II)}. \end{cases} \tag{2.22}$$

Here (I) is case I of reuse of the r-th IS element; (II) is case II of reuse of the r-th IS element.

Based on formulas (2.14)–(2.22), a detailed description of the loss model P_1 (2.1) for the case of IT project management of IS creation is proposed to be presented as follows

$$P_1 = k \times \sum_{z=1}^{R(H)} \left(\sum_{i=1}^{m} k_{zi} q_{zi}(T) St_{zi}(T) + \sum_{j=1}^{n} k_{zj} q_{zj}(T) CI_{zj}(T) \right), \tag{2.23}$$

or in a simplified case

$$P_1 = k \times \left(\sum_{z=1}^{R(H)} \sum_{i=1}^{m} k_{zi} q_{zi}(T) St_{zi}(T) + \sum_{z=1}^{R(H)} C_{Cl}(z) \right). \tag{2.24}$$

A detailed description of the loss model P_2 (2.2) for the case of IT project management of IS creation is proposed to be presented as follows

$$P_2 = k \times \left(\sum_{r=1}^{R(H)} S'_{repm,r} - \sum_{d=1}^{R(H)} \hat{S}_{repd,d} \right). \tag{2.25}$$

Expressions (2.14)–(2.25) allowed to state that the choice of the consequence Ex_1 will be appropriate only when the condition

$$P_{sum} = P_1 + P_2 \leq \sum_{d=1}^{R(H)} \hat{S}_{repd,d}, \tag{2.26}$$

is met, i.e. in situations where the costs of reusing the information being replaced do not exceed the costs of designing and implementing "from scratch" IS elements, the descriptions of which are incomplete or absent.

In the process of formulating a detailed description of the loss models (2.3) and (2.4), it was established that the main problem lies in clarifying the formal description of the parameter *b*. Based on the above-defined features of the processes of designing and implementing IS elements in an IT company, the following assumptions were formulated:

– Assumption 4: the transfer of personnel and elements of the IT infrastructure of an IT company from the IT project of creating IS A to the IT project of creating IS B is considered as replacing the backlog of tasks for developing IS elements A with the backlog of tasks for developing IS elements B;

– Assumption 5: the general mechanism for replacing information is single and unchanged for any IT project within an IT company.

Based on these assumptions, the value of the coefficient *b* is proposed to be calculated in the case of replacing the description of one IS element A with the description of one IS element B as follows

$$\beta = \hat{S}_{repd}^{IS_A} - \hat{S}_{repm}^{IS_B} \Big/ \hat{S}_{repd}^{IS_A}, \tag{2.27}$$

where $\hat{S}_{repd}^{IS_A}$ – the estimated value of information about the descriptions of the elements of IS A, which is being replaced; $\hat{S}_{repm}^{IS_B}$ – the estimated value of information about the descriptions of the elements of IS B, which is being replaced.

The value $\hat{S}_{repd}^{IS_A}$ for one d-th element of IS A, the description of which is absent or insufficient for the performance of work on the design and implementation of this element, is proposed to be calculated by formulas (2.19) or (2.20). The value $\hat{S}_{repm}^{IS_B}$ for one r-th element of IS B, the description of which is used during the formation of the team backlog instead of the description of the d-th element of IS A, is proposed to be calculated by formulas (2.17) or (2.18). Based on these estimates, expression (2.27) for the case of replacing the descriptions of two or more elements of IS A with descriptions of two or more elements of IS B was modified as follows

$$\beta=\left(\sum_{d=1}^{R(H)}\hat{S}_{repd,d}^{IS_A}-\sum_{r=1}^{R(H)}\hat{S}_{repm,r}^{IS_B}\right)\Big/\sum_{d=1}^{R(H)}\hat{S}_{repd,d}^{IS_A}. \tag{2.28}$$

The product $S_{res_{av}}^{t_{st}}\times I$ described the total resource costs for the normalized time period t_{st}. For the case of transferring resources involved in the design and implementation of the d-th element of IS A to perform work on the design and implementation of IS B, this product is proposed to be described as follows:

$$S_{res_{av},d}^{t_{st}}\times I_d=\hat{S}_{repd,d}^{IS_A}=\sum_{i=1}^{m}k_{di}^{IS_A}q_{di}^{IS_A}(T)St_{di}^{IS_A}(T)+\sum_{j=1}^{n}k_{dj}^{IS_A}q_{dj}^{IS_A}(T)CI_{dj}^{IS_A}(T), \tag{2.29}$$

$$S_{res_{av},d}^{t_{st}}\times I_d=\hat{S}_{repd,d}^{IS_A}=\sum_{i=1}^{m}k_{di}^{IS_A}q_{di}^{IS_A}(T)St_{di}^{IS_A}(T)+C_{CI}(d). \tag{2.30}$$

Then, in the general case, the product $S_{res_{av}}^{t_{st}}\times I$ as a set of resources that were planned to be used to perform $R(H)$ of the IS A elements, but due to the uncertainty of the descriptions of these elements, it is recommended to transfer them to the IS B IT project, is proposed to be described as follows

$$S_{res_{av}}^{t_{st}}\times I=\hat{S}_{repd}^{IS_A}=\sum_{d=1}^{R(H)}\hat{S}_{redp,d}^{IS_A}. \tag{2.31}$$

Based on formulas (2.27)–(2.31), a detailed description of the loss model P_3 (2.3) for the case of managing IT projects for the creation of IS A and IS B is proposed to be presented as follows

$$P_3=\frac{\sum_{d=1}^{R(H)}\hat{S}_{repd,d}^{IS_A}-\sum_{r=1}^{R(H)}\hat{S}_{repm,r}^{IS_B}}{\sum_{d=1}^{R(H)}\hat{S}_{repd,d}^{IS_A}}\times\sum_{d=1}^{R(H)}\hat{S}_{redp,d}^{IS_A}\times t_{indef}(H)k_1 \tag{2.32}$$

provided that $t_{indef}(H)\geq T$.

A detailed description of the loss model P_4 (2.4) for the case of managing IT projects for the creation of IS A and IS B is proposed to be presented as follows

$$P_4 = \frac{\sum_{d=1}^{R(H)} \hat{S}_{repd,d}^{IS_A} - \sum_{r=1}^{R(H)} \hat{S}_{repm,r}^{IS_B}}{\sum_{d=1}^{R(H)} \hat{S}_{repd,d}^{IS_A}} \times \sum_{d=1}^{R(H)} \hat{S}_{redp,d}^{IS_A} \times Tk_1 \tag{2.33}$$

provided that $t_{indef}(H) < T$.

In the process of formulating a detailed description of the loss models (2.5) and (2.6), the following assumptions were made:

– Assumption 6: for any IT project to create an IS, there is always a project backlog as a set of tasks, the design and implementation of which is planned within the framework of a set of iterations of this IT project;

– Assumption 7: any backlog of a development team can be described as a set consisting of two disjoint subsets – a subset of main tasks, which is necessarily non-empty, and a subset of reserve tasks, which may be empty.

The elements of the subset of mandatory tasks of the team backlog are tasks planned for design and implementation by the team in the current iteration. The elements of the subset of reserve tasks of the same backlog are tasks that are provided for design and implementation to team representatives in the event of either their full completion of all assigned mandatory tasks, or recognition of the impossibility of performing assigned mandatory tasks due to the absence or uncertainty of the description of these tasks.

Based on these assumptions, the definition of losses arising as a result of Ex_3 is proposed to be specified as follows: P_5 – losses from transferring personnel and IT infrastructure elements of the IT company to perform the task of designing and implementing an IS element in the case when it is selected from the project backlog; P_6 – losses from transferring personnel and IT infrastructure elements of the IT company to perform the task of designing and implementing an IS element in the case when it is selected from the subset of reserve tasks of the development team backlog.

Initially, the situation of P_5 losses was considered. In this case, a situation arises of replacing one or more tasks for the design and implementation of an IS element, the descriptions of which are missing or not defined with sufficient accuracy, with the corresponding number of tasks from the project backlog, the descriptions of which are fully defined. Then the estimate of the average cost $S_{av.nc.w}$ of a unit of work not performed as a result of the transfer of resources, by analogy with formulas (2.19) and (2.20), should be described as follows:

$$\hat{S}_{av.nc.w}=\sum_{i=1}^{m}k_{di}q_{di}(T)St_{di}(T)+\sum_{j=1}^{n}k_{dj}q_{dj}(T)CI_{dj}(T), \tag{2.34}$$

$$\hat{S}_{av.nc.w}=\sum_{i=1}^{m}k_{di}q_{di}(T)St_{di}(T)+C_{CI}(d), \tag{2.35}$$

where d – an IS element, the description of which is incomplete or missing at the time of iteration planning.

The estimate of the cost $\hat{S}_{unfin.w}$ of performing unfinished work, to which the personnel and IT infrastructure elements of the IT company were transferred, selected from a random set of unfinished work of the IS creation IT project, by analogy with formulas (2.17) and (2.18), should be described as follows:

$$\hat{S}_{unfin.w}=\sum_{i=1}^{m}k_{ri}q_{ri}(T)St_{ri}(T)+\sum_{j=1}^{n}k_{rj}q_{rj}(T)CI_{rj}(T), \tag{2.36}$$

$$\hat{S}_{unfin.w}=\sum_{i=1}^{m}k_{ri}q_{ri}(T)St_{ri}(T)+C_{CI}(z), \tag{2.37}$$

where r – an IS element, the fully defined description of which is selected from the project backlog.

As for the value of the parameter W_{sum}, in the general case it should be determined based on the policy of penalties for failure to perform work within certain time intervals, which is fixed in the contract for the implementation of the IT project. This contract is concluded between an IT company acting as an IT Service Provider (developer, IT project performer, etc.) and an organization or individual acting as an IT Service Consumer (customer, etc.). One of the classic examples of such a policy is the decision to pay a penalty as a predetermined percentage of the cost of an IT project for each working day during which the work remains unperformed. For this example, the parameter W_{sum} will take the value

$$W_{sum}=tk_{\%}P_{project}, \tag{2.38}$$

where t – the time period under consideration; $k_{\%}$ – penalty coefficient, $k_{\%}\in[0,...,1]$, the value of which is fixed in the text of the contract for the implementation of the IT project; $P_{project}$ – cost of the IT project, the value of which is fixed in the text of the contract for the implementation of the IT project.

Based on formulas (2.34)–(2.38), a detailed description of the P_5 (2.5) loss model for the case when the task for replacement is selected from the project backlog is proposed to be presented as follows

$$P_5 = \left(\frac{R(H)t(\sum_{i=1}^{m} k_{di} q_{di}(T) St_{di}(T) + \sum_{j=1}^{n} k_{dj} q_{dj}(T) CI_{dj}(T)) t_{indef}(H)}{Tt_c} + tk_{\%} P_{project} \right) -$$

$$- \left(\sum_{i=1}^{m} k_{ri} q_{ri}(T) St_{ri}(T) + \sum_{j=1}^{n} k_{rj} q_{rj}(T) CI_{rj}(T) \right) \quad (2.39)$$

provided that $t_{indef}(H) \geq T$. Otherwise, it should be assumed that $t_{indef}(H) = T$.

Next, the situation of P_6 loss occurrence was considered. In this case, a situation arises of replacing one or more tasks for the design and implementation of an IS element, the descriptions of which are absent or not determined with sufficient accuracy, with the corresponding number of tasks from the development team backlog, the descriptions of which are fully determined. The estimate of the average cost $S_{av.nc.w}$ of a unit of work not performed as a result of the transfer of resources, in this case should be calculated using formulas (2.34), (2.35). The value of the parameter W_{sum} should be calculated using formula (2.38).

To calculate the value of the parameter $S_{reserve}$, it was proposed to consider the creation of the development team backlog as a task for the performance of which the appropriate personnel and resources are involved. The result of such a task is the development team backlog as a team activity plan for the time period *T*. Therefore, in the general case, $S_{reserve}$ should be calculated using formulas:

$$\hat{S}_{reserve} = \sum_{i=1}^{m} k_{pi} q_{pi}(T) St_{pi}(T) + \sum_{j=1}^{n} k_{pj} q_{pj}(T) CI_{pj}(T), \quad (2.40)$$

$$\hat{S}_{reserve} = \sum_{i=1}^{m} k_{pi} q_{pi}(T) St_{pi}(T) + C_{CI}(p), \quad (2.41)$$

where *p* – conditional resources (IT project staff and other resources) that were used to perform the work on planning the activities of the IT project team.

The cost of the completed work reserve $S_{compl.w.reserve}$ in this case is equal to the cost of tasks from the backlog reserve of the development team that were performed instead of tasks, which descriptions were recognized as incomplete. In this case, developers can only operate with an estimate of the value $S_{compl.w.reserve}$. This estimate, by analogy with (2.17), (2.18), is proposed to be determined as follows:

$$\hat{S}_{compl.w.reserve} = \sum_{res=1}^{r} \sum_{i=1}^{m} k_{resi} q_{resi}(T) St_{resi}(T) + \sum_{res=1}^{r} \sum_{j=1}^{n} k_{resj} q_{resj}(T) CI_{resj}(T), \quad (2.42)$$

$$\hat{S}_{compl.w.reserve} = \sum_{res=1}^{r}\sum_{i=1}^{m} k_{resi} q_{resi}(T) St_{resi}(T) + C_{CI}(z), \tag{2.43}$$

where *res* – the IS element, the description of which is decided to be selected from the backlog reserve of the development team and used instead of the incomplete description of the IS element, which cannot be implemented during the current iteration. The value of the quantity q_{ri} is set by a formula similar to (2.16).

Based on formulas (2.34), (2.35), (2.38) and (2.40)–(2.43), a detailed description of the loss model P_6 (2.6) for the case when the task for replacement is selected from the backlog of the development team is proposed to be presented as follows

$$P_6 = \left(\frac{R(H)t\left(\sum_{i=1}^{m} k_{di} q_{di}(T) St_{di}(T) + \sum_{j=1}^{n} k_{dj} q_{dj}(T) CI_{dj}(T)\right) t_{indef}(H)}{Tt_c} + \atop + tk_{\%} P_{project} + \sum_{i=1}^{m} k_{pi} q_{pi}(T) St_{pi}(T) + \sum_{j=1}^{n} k_{pj} q_{pj}(T) CI_{pj}(T) \right) -$$

$$- \sum_{res=1}^{r}\sum_{i=1}^{m} k_{resi} q_{resi}(T) St_{resi}(T) - \sum_{res=1}^{r}\sum_{j=1}^{n} k_{resj} q_{resj}(T) CI_{resj}(T) \tag{2.44}$$

provided that $t_{indef}(H) \geq T$. Otherwise, it should be assumed that $t_{indef}(H) = T$.

When developing detailed descriptions of costs P_7 (2.7) and P_8 (2.8), it was taken into account that the product $S_{res_{av}}^{t_{st}} \times I$, which determined the total resource costs for the normalized time period t_{st}, was already described by expressions (2.29)–(2.31). In this case, the difference is that the set of resources that were planned to be used to perform $R(H)$ of the IS A is elements not transferred to the IS B IT project and is not used in any of the IT projects. Therefore, it was proposed to present the detailed descriptions of costs P_7 (2.7) and P_8 (2.8) as follows

$$P_7 = \left(\sum_{d=1}^{R(H)} \hat{S}_{redp,d}^{IS_A} \right) \times t_{indef}(H) R(H) \tag{2.45}$$

provided that $t_{indef}(H) \geq T$;

$$P_8 = \left(\sum_{d=1}^{R(H)} \hat{S}_{redp,d}^{IS_A} \right) \times TR(H) \tag{2.46}$$

provided that $t_{indef}(H) < T$.

In this case, the value of each element of the sum $\sum_{d=1}^{R(H)} \hat{S}_{redp,d}^{IS_A}$ is calculated using expressions (2.29) or (2.30).

For a detailed description of losses due to the consequences Ex_5 and Ex_6, which are the results of the consequences Ex_2, Ex_3 and Ex_4, it was necessary to conduct additional research. The main goal of these studies was to study the features of planning multiple iterations of an IT project for creating an IS due to an increase or decrease in the duration of a separate iteration *T*. Therefore, in this study, a detailed description of losses due to the consequences Ex_5 and Ex_6 was not considered.

2.6 Experimental verification of the obtained results

2.6.1 Description of the initial data

To verify the results obtained, it was proposed to use the data of the IT project for the development of the service "Electronic Compulsory Motor Third Party Liability Insurance Policy" (CMTPL). The sale of this type of insurance policy was officially launched in Ukraine in accordance with the changes in the legislation of February 7, 2018. In this regard, the problem of developing and implementing IT services that allow automating such activities arose.

The IT company ProfITsoft, a leading software development company that also has deep expertise in the insurance domain and innovations in the InsurTech industry, was engaged in solving this problem. It has been implementing IT projects for the development and maintenance of software for more than 20 years. In the Ukrainian market, ProfITsoft is known as the developer of the IS "Comprehensive System for Automation of Insurance Company Work – ProfITsoft" (KSASK), which is successfully used by leading insurance companies [16].

The KSASK development began in 2006, when the functional module "Front-office" was introduced. The following functions were developed within this module [17]: "Calculators", "Sales network", "Forms", "Commission", "Security".

In 2009, the system was supplemented with the functional module "Back-office". The following functions were developed within this module [17]: "Metadata-based interface", "Finance", "Settlement", "Reinsurance".

In 2013, KSASK implemented designers – tools that allow to configure any calculations, documents and output forms without the need to modify the entire system or its individual modules. In addition, the functional modules "Underwriting" and "Import of contracts" [17] were implemented during this period.

In 2014–2019, KSASK gradually transitioned from a modular to a service architecture. In addition, the following modules were developed in the system [17]: "Online-shop" (aka "Internet store"), "Settlement designer", "Integrations" (a module that supports data exchange via API with external platforms (EWA, PrivatBank, etc.)).

By 2021, KSASK had developed as follows [17]:

– calculator designer was developed;

– "Financial monitoring" and "Quote requests" services were developed;

– mobile version of KSASK software was developed;

– transition from a service to a microservice architecture of the system began.

In 2022–2024, KSASK was adapted to the new requirements of the National Bank of Ukraine, which came into force in 2024 in accordance with the Law "On Insurance" (No. 1909-IX). As a result of the adaptation, KSASK began to provide automation of all business processes of insurance companies, in particular, accounting of contracts, financial monitoring, formation and submission of reports in accordance with the requirements of the regulator. The system supports electronic signatures and integration with key state registers and services, ensuring reliability, transparency and control of all operations. KSASK has already been updated to comply with new classifications of insurance products and accounting by business lines, which makes it a reliable solution for meeting the requirements of the National Bank of Ukraine [18].

At the time of the initiation of the IT project for the development of the "Electronic CMTPL Policy" service (2017), the basic version of KSASK consisted of the following functional modules:

– "Insurance Calculator";

– "Accounting for Contracts";

– "Import of Data Lists";

– "Underwriting";

– "Accounting for Forms";

– "Commissions";

– "Finances";

– "Settlement";

– "VMI" (voluntary medical insurance);

– "Reporting to the Motor (Transport) Insurance Bureau of Ukraine (MTBU)";

– "Online Store";

– "Administration";

– "CRM";

– "Business Processes";

– "Releases";

– "Help".

The service "Electronic CMTPL Policy", the development of which was the main goal of the IT project, according to the requirements set for it, was to consist of the following functions:

– "Filling out an electronic policy";
– "Checking an electronic policy";
– "Issuing an electronic policy";
– "Selling an electronic policy";
– "Printing an electronic policy agreement";
– "Checking the validity period of an electronic policy";
– "Paying for an electronic policy";
– "Calculating the commission fee for an electronic policy";
– "Authorization via SMS".

The emergence of a business opportunity to sell an electronic CMTPL policy has led to the emergence of a corresponding business need in insurance companies. Therefore, ProfITsoft has identified the minimization of the time for the development and implementation of this service as an additional condition for the successful implementation of the IT project for the development of the "Electronic CMTPL Policy" service. It was believed that the fulfillment of this condition would allow insurance companies-owners of KSASK to gain a temporary business advantage over competitors (until the implementation of similar services from other developers). The main way to fulfill this condition during the initiation of the project was to reuse the results of the development of other functional KSASK modules. To search for functional KSASK modules and their functions that can be reused in the IT project for the development of the "Electronic CMTPL Policy" service, the information technology of the IT service provision management system was used [19]. The theoretical foundations and features of the implementation of this technology are discussed in detail in [20]. At the moment, this technology in the IT company ProfITsoft has received further development and has become a specialized mechanism "Functional Exchange Fund". This mechanism of interaction between insurance companies-users of KSASK provides the possibility of transferring, exchanging, reusing and collectively developing the modified functionality of the system [21].

The results of the search for functional modules and individual functions of KSASK suitable for reuse in the IT project for the development of the "Electronic CMTPL Policy" service are given in **Table 2.1**.

As a result of the application of information technology for managing the IT service provision system during the initiation of the IT project, an assessment of the profitability of independent service development or reuse of one of the KSASK IT service search results (functions) listed in **Table 2.1** was carried out.

The ISO/IEC 1926:2001 criteria system was used for the assessment [22]. The assessment was carried out according to the IT service selection method proposed in [20], which is based on the hierarchy analysis method.

Table 2.1 Results of the search for functional modules and individual functions of KSASK suitable for reuse in the IT project for the development of the "Electronic CMTPL Policy" service

Search object	IT service search result	Search result for the name/part of the name that matches, IT service function
Full match with the list of functional requirements	No IT services found that fully implement all functional requirements	
IT services that fully implement individual functional requirements	"Online store"	"Authorization via SMS"
IT services that implement individual parts of the functional requirements	"Online store"	– "Filling"; – "Policy registration"; – "Registration"; – "Sale"; – "Payment"; – "Print"; – "SMS"; – "Authorization via SMS"
	"Accounting for Contracts"	– "Verification"; – "Contract verification"; – "Print"; – "Term"; – "Print contract"
	"Commissions"	– "Commissions"; – "Calculation"; – "Print"; – "Verification"
	"Underwriting"	– "Verification"; – "Policy verification"; – "Policy"

Source: [20]

The assessment resulted in the following recommendations [20]:

– the best solution according to the selected criteria is the development of the "Electronic CMTPL Policy" service "from scratch";

– for reuse during the implementation of the IT project for the development of the "Electronic CMTPL Policy" service, the most suitable are the functions of the "Contract Accounting" and "Online Store" modules.

To experimentally verify the results obtained in the study, it was proposed to check the correctness of these recommendations at different stages of the IT project life cycle for the development of the "Electronic CMTPL Policy" service. In particular, it was proposed to consider solutions for the formation and adjustment of IT project plans, based on estimates of losses that may arise as a result of identifying the fact of incompleteness of the description of a separate IT project function.

2.6.2 Description of the assessment of losses due to the replacement of incomplete information with information about a similar element of the information system at the stage of IT project initiation

First of all, the assessment of losses due to the replacement of incomplete information about the functions of the "Electronic CMTPL Policy" service with information about similar functions of the KSASK at the stage of IT project initiation was considered. For comparison, an assessment of the costs of developing the "Electronic CMTPL Policy" service "from scratch" was also carried out.

To calculate the costs of developing the "Electronic CMTPL Policy" service "from scratch", it was proposed to use:

– COCOMO model [15];

– a simplified method of functional points [23], which allows to estimate the efforts for the development of IS elements in conditions of almost complete absence of information about new IS functions;

– a backfiring technique for converting the number of functional points into the number of lines of source code (as an argument of the COCOMO model).

The values of the parameters of the simplified functional point method, the rollback coefficient k and the COCOMO model are given in **Table 2.2**.

As a result of calculating the number of functional points of the "Electronic CMTPL Policy" service, it was obtained

$$FP = (C_1 + C_2 + C_3)^{2.35} = (9 + 9 + 15)^{2.35} = 33^{2.35} \approx 3702.61 \text{ (functional points)}.$$

The results of calculating the estimates of efforts, time costs and personnel requirements for the IT project for developing the "Electronic CMTPL Policy" service "from scratch" using the COCOMO model are given in **Table 2.3**.

Table 2.2 Values of the parameters of the simplified functional point method and the rollback coefficient *k* and the COCOMO model

Element name	Element value	Explanation
C_1	9	Estimation of the project scale ("Custom application")
C_2	9	Estimation of the users of the design object ("Commercial project")
C_3	15	Estimation of the type of design object ("Software for publicly available services")
k_{DB}	16	Maximum normative number of SQL commands per one functional point
k_{SW}	46	Maximum normative number of Java commands per one functional point
B_d	1.12	Locked mode of operation (application system development)

Source: [23]

Table 2.3 Results of calculating the characteristics of the IT project for developing the "Electronic CMTPL Policy" service "from scratch"

Characteristic name	Characteristic value	Units of measurement
Service database development		
E_{DB}	174.37	Person-months
T_{DB}	17.77	Months
SS_{DB}	9.81	Full-time and part-time employees
Service software development		
E_{SW}	524.49	Person-months
T_{SW}	27.08	Months
SS_{SW}	19.51	Full-time and part-time employees

It should be remembered that the estimates of the characteristics of an IT project at the stage of its initiation may significantly deviate from the real characteristics of the same project. According to the research results given in [15], such estimates may exceed the value of the real characteristic by four times. Based on this, it was proposed to adjust the characteristics of the IT project given in **Table 2.3** by dividing the number of functional points by four (the result is 925.6525 functional points). The results of the adjustment are given in **Table 2.4**.

The data in **Table 2.4** show that even in the case of organizing parallel development of the database and software for the "Electronic CMTPL Policy" service, the duration of the IT project will be approximately 1 year and 4 months. This duration was recognized as unacceptable from the point of view of meeting the business needs of insurance companies-users of KSASK (even considering that the decision to develop the "Electronic CMTPL Policy" service "from scratch" was recognized as the best according to the criteria for the quality of software product development).

Table 2.4 Adjusted results of calculations of the characteristics of the IT project of the development the "Electronic CMTPL Policy" service "from scratch"

Characteristic name	Characteristic value	Units of measurement
	Service database development	
E_{DB}	40.67	Person-months
T_{DB}	10.22	Months
SS_{DB}	3.98	Full-time and part-time employees
	Service software development	
E_{SW}	123.28	Person-months
T_{SW}	15.58	Months
SS_{SW}	7.914	Full-time and part-time employees

Next, an assessment of possible losses due to replacing incomplete information about the functions of the "Electronic CMTPL Policy" service with information about similar functions of the "Online Store" module of KSASK at the stage of IT project initiation was carried out. This option was chosen because, according to the search results given in **Table 2.1**, it showed the largest number of matches.

It was decided to exclude from further consideration those search results given in **Table 2.1**, which are parts of other search results for functions of the same module. The result of excluding duplicate search results and further comparison of the names of the functions of the service "Electronic CMTPL Policy" and the functions of the module "Online Store" is given in **Table 2.5**. In addition, **Table 2.5** indicates the estimates of the number of functional points for each of the functions of the service being developed and the value of the number of functional points for the functions of the module.

Since at the stage of IT project initiation, the executors only know the names of individual functions of the service being developed, it was proposed to consider the distribution of efforts for the development of individual functions of the service as uniform. Therefore, for further calculations, the value of the effort spent on the development of each individual function of the service was taken as 102.85 (functional points).

Table 2.5 Comparison of the names of the functions of the "Electronic CMTPL Policy" service and the "Online Store" module

No.	Service function name	Number of service function points	Name of the module function highlighted in the search results	Number of functional points of the module function
1	"Filling out an electronic policy"	102.85	"Filling out an insurance contract"	97
2	"Issuing an electronic policy"	102.85	"Issuing an insurance policy"	84
3	"Selling an electronic policy"	102.85	"Selling an order"	157
4	"Printing an electronic policy agreement"	102.85	"Printing the source document"	48
5	"Paying for an electronic policy"	102.85	"Paying for the insurance contract"	142
6	"Authorization via SMS"	102.85	"Authorization via SMS"	134

For further calculations, it was proposed to use:

– the COCOMO model [15];

– the improved functional points method [24], which allows to estimate the efforts for the development of IS elements in the conditions of reuse of individual system functions;

– the backfiring technique for converting the number of functional points into the number of lines of source code (as an argument of the COCOMO model).

To determine the number of developers $q_{zj}(T)$ required to eliminate the situation under consideration, the expression (16) was used, which in this case took the form

$$q_{zi}(T) = \frac{2.4(KLOC_z)^{B_z}}{T} = \frac{2.4(k_z FP_{add,z}/1000)^{B_z}}{T}, \tag{2.47}$$

where $KLOC_z$ – the number of thousands of lines of source code, the creation of which is necessary for additional processing with information that replaces; k_z – the rollback coefficient, which determines the normative number of lines of source code for the implementation of one functional point of the z-th IS function; $FP_{add,z}$ – the number of functional points as an estimate of the efforts for additional processing with information that replaces an incomplete description of the z-th IS function; B_z – an indicator, the value of which is determined by the selected mode of additional processing with information that replaces an incomplete description of the z-th IS function.

To calculate the value of $FP_{add,z}$ in [24] it was proposed to use the expression

$$FP_{add,z} = FP_z \times \left(\frac{|Name_d - Name_z|}{|Name_z|} \right), \tag{2.48}$$

where FP_z – the number of functional points, which is an estimate of the efforts to develop the *z*-th function of the developed functional problem; $Name_d$ – the name of the *d*-th function of the developed problem, the description of which is incomplete; $Name_z$ – the name of the *z*-th function of the developed functional problem.

Based on formula (2.48), to calculate the $FP_{add,z}$ value it was necessary to perform stemming of the names of individual service functions and their corresponding module functions with the subsequent removal of stopwords. The results of these operations using the Porter stemmer are given in **Table 2.6**.

The FP_z values for each of the module functions, the descriptions of which are proposed to be reused in the IT project for the development of the "Electronic CMTPL Policy" service, are given in **Table 2.5**. These values, as established for case I, are one of the results of the analysis of previous IT projects of the company ProfITsoft.

Then, according to expression (2.48) for $z = 1$, there is the following number of functional points

$$FP_{add,1} = 97 \times \left(\frac{|\text{"Fill electron polici"} - \text{"Fill insur contract"}|}{|\text{"Fill insur contract"}|} \right) =$$

$$= 97 \times \left(\frac{2}{3} \right) = 64.67 \text{ (functional points).}$$

The results of calculating the $FP_{Add,z}$ values for all functions are given in **Table 2.7**.

The values of the elements of formula (2.47), which were used to experimentally verify the results obtained during the assessment of losses in the situation under consideration, are given in **Table 2.8**.

As a result of the calculation according to formula (2.47) for $z = 1$, it is possible to obtain

$$q_1(T) = \frac{2.4(46 \times 64.67/1000)^{1.12}}{2} = \frac{2.4(2.97482)^{1.12}}{2} = \frac{8.136}{2} = 4.068 \text{ (man).}$$

The results of the calculations of the $q_z(T)$ values given in **Table 2.9**.

Table 2.6 An example of the result of using the Porter stemmer for function names

Pre-processing stage	Title of replaced function	Title of replacement function
Original frame name	Filling in an electronic policy	Filling out an insurance contract
Results of using Porter's stemmer	Fill in an electron policy	Fill out an insure contract
Stopword removal results	Fill electron policy ($Name_d$)	Fill out an insure contract ($Name_z$)
Original frame name	Electronic policy registration	Insurance policy registration
Results of using Porter's stemmer	Electron policy register	Insure policy register
Stopword removal results	Electron policy register ($Name_d$)	Insure policy register ($Name_z$)
Original frame name	Selling an electronic policy	Selling an order
Results of using Porter's stemmer	Sell an electron policy	Sell an order
Stopword removal results	Sell electron policy ($Name_d$)	Sell order ($Name_z$)
Original frame name	Print-out an electronic policy	Print-out the original document
Results of using Porter's stemmer	Print-out an electron policy	Print-out the origin document
Stopword removal results	Print-out electron policy ($Name_d$)	Print-out origin document ($Name_z$)
Original frame name	Payment of an electronic policy	Payment of an insurance contract
Results of using Porter's stemmer	Payment of an electron policy	Payment of an insure contract
Stopword removal results	Payment electron policy ($Name_d$)	Payment insure contract ($Name_z$)
Original frame name	Authorization via SMS	Authorization via SMS
Results of using Porter's stemmer	Author via SM	Author via SM
Stopword removal results	Author SM ($Name_d$)	Author SM ($Name_z$)

Table 2.7 Results of calculations of $FP_{Add,z}$ values for all functions, the reuse of which is proposed in the IT project

Parameter	Parameter value					
z	1	2	3	4	5	6
$FP_{Add,z}$	64.67	28	157	32	94.67	0

Table 2.8 Values of the elements of formula (2.47), selected for the quantitative assessment of possible losses

Element name	Element value	Explanation
k_z	46	Maximum standard number of Java commands per functional point
B_z	1.12	Locked mode of operation (application system development)
T	2 months/4 iterations	Iteration duration – 12 working days

Table 2.9 Results of the calculations of the $q_z(T)$ values for all functions which reuse is proposed in the IT project

Parameter	Parameter value					
z	1	2	3	4	5	6
$q_z(T)$	4.068	1.5936	10.992	1.848	6.24	0

Then it was decided to calculate by formula (2.24) the value of losses P_1 from the absence of information in case of need for additional processing with information that replaces. The values of the elements of formula (2.24), which were used to experimentally verify the obtained results when estimating losses in the situation under consideration, are given in **Table 2.10**.

The standard salary of a specialist at ProfITsoft was determined based on the labor costs of the KSASK technical support team given in [25].

Based on these values, the losses P_1 are equal to

$$P_1 = 1\times\left(\sum_{z=1}^{6}\sum_{i=1}^{m} k_{zi} q_{zi}(T) St_{zi}(T) + \sum_{z=1}^{1} C_{CI}(z)\right) = 1\times\left(k_z \times T \times \sum_{z=1}^{6} q_z(T) St_z(T) + \sum_{z=1}^{6} C_{CI}(z)\right) =$$
$$= 1\times(500\times4\times24.7416 + 240) = \$49723.2.$$

Next, it was decided to calculate the value of the losses P_2 from the absence of information using formula (2.25) if there is a difference in the cost of the information being replaced and the information being replaced. Since the *z*-th functions, the descriptions of which are proposed to be used instead of the descriptions of the *d*-th functions, were developed in previous IT projects of ProfITsoft, it was decided to use the calculation rule established for case I.

Table 2.10 Values of the elements of formula (2.24), selected for quantitative assessment of possible losses

Element name	Element value	Explanation
$C_{CI}(z)$	$40	Electricity costs and additional costs
$St_{zi}(T)$	1	The fact that the developer is in the process of creating the *z*-th element of the IS during the time period *T* at the *i*-th position
k_z	$500	The standard salary of a company specialist during the iteration
$R(H)$	6	The number of cases of incompleteness or lack of information
k	1	The value of the quality coefficient of management decision-making

First, an estimate of the personnel requirement was determined. For the example under consideration, formula (2.16) took the form:

$$q_z(T)=\frac{2.4(KLOC_z)^{B_z}}{T}=\frac{2.4(k_zFP_z/1000)^{B_z}}{T}, \tag{2.49}$$

$$q_d(T)=\frac{2.4(KLOC_d)^{B_d}}{T}=\frac{2.4(k_dFP_d/1000)^{B_d}}{T}, \tag{2.50}$$

where $KLOC_d$ – the number of thousands of lines of source code that must be created to implement the *d*-th function; k_d – rollback coefficient, which determines the normative number of lines of derived code for the implementation of one functional point of the *d*-th IS function; FP_d – the number of functional points as an estimate of the efforts to develop the *d*-th IS function; B_d – an indicator, the value of which is determined by the selected mode of development of the *d*-th IS function.

The FP_d values for the service functions that are proposed to be replaced are given in **Table 2.5**. The $q_z(T)$ values are given in **Table 2.9**.

The values of the elements of formula (2.50), which were used to experimentally verify the obtained results when assessing losses in the situation under consideration, are given in **Table 2.11**.

As a result of the calculation by formula (2.50) for each of the *d*-th functions, the descriptions of which are incomplete

$$q_d(T)=\frac{2.4(k_d FP_d/1000)^{B_d}}{T}=\frac{2.4(46\times102.85/1000)^{1.12}}{2}=$$
$$=\frac{2.4(4.7311)^{1.12}}{2}\approx\frac{13.683}{2}\approx6.84\ \text{(man)}.$$

The values of the estimates of the value of the information S_{repm} being replaced were established based on the results of the analysis of previously completed IT projects. From these results it turned out that on average for each individual function the value S_{repm} is equal to \$12000. The value of the estimate of the replaced information was calculated by formula (2.20). The values of the elements of formula (2.20) used for the calculation are given in **Table 2.12**.

Table 2.11 The values of the elements of formula (2.50), selected for quantitative assessment of possible losses

Element name	Element value	Explanation
k_d	56	Maximum regulatory number of Java commands per functional point
B_d	1.12	Locked mode of operation (application system development)

Table 2.12 The values of the elements of formula (2.20) selected for the calculation of the estimates of the values of the replaced information

Element name	Element value	Explanation
$C_{Cl}(z)$; $C_{Cl}(d)$	\$40	Electricity costs and additional costs
$St_{ri}(T)$; $St_{di}(T)$	1	The fact that the developer is in the process of creating the *z*-th element of the IS during the time period *T* at the *i*-th position
k_r; k_d	\$500	The standard salary of a company specialist during the iteration
k	1	The value of the quality coefficient of management decision-making

Then, according to formula (2.25), the value of losses P_2 is equal to

$$P_2=1\times\left(\sum_{r=1}^{6}\hat{S}_{repm,r}-\sum_{d=1}^{6}\hat{S}_{repd,d}\right)=1\times\left(6\times(12000+40)-6\times(13680+40)\right)=$$
$$=1\times\left(6\times12040-6\times13720\right)=-\$10080.$$

As a result of checking the fulfillment of condition (2.26) of the feasibility of choosing the consequence Ex_1, it was established that

$$P_{sum} = P_1 + P_2 = 49723.2 - 10080 = \$39643.2;$$

$$\sum_{d=1}^{6} \hat{S}_{repd,d} = \$81080; \$39643.2 \leq \$81080,$$

that is, the reuse of software descriptions of the functions of the "Online store" module to eliminate the incompleteness of the software descriptions of the functions of the "Electronic CMTPL Policy" service is feasible subject to the following conditions for the implementation of the IT project for the development of the "Electronic CMTPL Policy" service:

– the total duration of the IT project, according to the estimate, should be 2 months;

– the total number of personnel for the implementation of the IT project, according to the estimate, should be 25 people (5 teams of 5 people each [25]);

– during the implementation of the IT project, the same software development tools will be used as in previous IT projects of the ProfITsoft company.

2.7 Discussion of the results of the loss assessment for the considered solution options

To eliminate the situation that arose during the initiation of the IT project for the development of the "Electronic CMTPL Policy" service due to incomplete descriptions of the functions of this service, two management solution options were proposed. The first option, proposed by the staff of the Department of Information Control Systems (ICS) of the Kharkiv National University of Radio Electronics (NURE), was based on the results of evaluating alternatives according to the ISO/IEC 1926:2001 software product quality criteria system. According to this option, it was proposed to abandon the reuse of previously developed KSASK functions and develop the service "from scratch". The alternative proposed by the authors of this study was to use descriptions of previously developed functions of the KSASK module "Internet Store" instead of incomplete descriptions of the service functions.

The results of the comparison of these two solution options are given in **Table 2.13**.

Based on the estimates given in **Table 2.13**, in order to minimize the total financial costs for wages and reduce the total time of implementation of the IT project, it is necessary to choose an alternative management solution.

But such a solution causes a certain increase in the risk of deterioration in the quality of the service being developed. In particular, after the implementation of the IT project for the development of the service "Electronic CMTPL Policy" according to the alternative option, the following sets of errors may exist in the service code:

– errors remaining in the software of reused KSASK functions after its adaptation to the requirements of the service;

– errors that arose in the software of the service functions during its adaptation to the requirements of the service.

Table 2.13 Results of the comparison of the characteristics of the proposed solution options for the IT project

Characteristics	Characteristic value	
	First option	Alternative
Total duration of the IT project	15.58 months	2 months
Requirement for personnel of the IT project	7.914 people	25 people
Nominal value of the salary of a company specialist during the iteration	$500	$500
Average number of iterations per month	2	2
Estimation of the total financial costs for salaries in the IT project	$123300.12	$50000

Of course, some subsets of these sets of errors will be detected during testing of the service software. But testing, as a rule, does not guarantee the detection of the full set of errors (especially in IT projects with a limited duration). However, the alternative solution involves the possibility of increasing the time spent on testing the service software (which will lead to an increase in the total time spent on the implementation of the IT project). Even if the total duration of the IT project is increased by 2 months, the total salary costs will not exceed the similar costs for the first option.

It should also be noted that the correctness of the alternative solution is emphasized by the fact that in the current (2024–2025) KSASK version, the "Electronic CMTPL Policy" service is implemented as a widget of the "Online Store" service [26].

Thus, in the course of this study, detailed models of production losses due to the lack of information were developed, adapted to the specifics of the IT company and its IT projects. The developed models allow to quantitatively assess the costs that arise during the initiation, planning and implementation of the IT project of creating an IS during the elimination of incomplete descriptions of individual system elements. These costs are the result of one of the following possible consequences:

– consequence Ex_1: "Replacing missing information with information about a similar IS element that is reused";

– consequence Ex_2: "Concentration of IT company personnel and IT infrastructure elements on the design or development of other IS elements";

– consequence Ex_3: "Transferring IT company personnel and IT infrastructure elements to the design or development of other elements of the same IS";

– consequence Ex_4: "Refusal to use IT company personnel and IT infrastructure elements due to the lack of information about IS elements".

The results obtained take into account the iterative nature of planning the activities of IT project teams and can be used for the majority of modern Agile and hybrid IT project management methodologies.

Unlike modern models and methods of IT project financial management [2], the implementation of the developed detailed models allows to estimate losses and make decisions on IT project cost management in the absence of a priori defined descriptions of individual IS elements (functions), which is the expected result of the project. The use of these models allows to choose solutions during the implementation of the IT project that minimize additional losses that arise in the following situations:

– a priori incompleteness of the results of the collection and analysis of functional requirements for the created system;

– the occurrence of a significant number of changes in the descriptions of functional requirements and IS architecture and its elements due to changes in the business processes of the automation object;

– the occurrence of changes in the descriptions of functional requirements and IS architecture and its elements due to the elimination of errors made during the design and implementation of individual elements of the created IS.

However, the use of the developed detailed loss models is not free from some limitations. The main limitation of these is the orientation of the developed detailed loss models to the assessment of direct losses exclusively during the period of time considered at the current stage of the project life cycle (the total duration of the IT project during the initiation and start of its planning; the total duration of the current iteration during the planning of the activities of the team of performers and the implementation of the IT project). The developed models practically do not take into account indirect losses that arise after making a decision on the selected consequence. Such a limitation during the practical application of the developed models may lead to the selection of a solution option that will be a local, rather than a global minimum of losses for the entire IT project or its individual iterations. Another limitation of the application of the obtained models is the implicit assumption of the constant availability of the relevant IT project performers and other resources. It is believed that these resources can be used at any time to eliminate the specified consequences of detecting incomplete information. In fact, the results of accounting for the workload of personnel and other material resources of an IT project can significantly change the estimates of possible losses that arise during the elimination of the identified incompleteness of information about the elements of the created IS.

The main drawback of the results of the study is the lack of technological sophistication of the developed detailed models. It should be remembered that the use of the obtained mathematical models in the IT company management system is impossible without conducting scientific and applied research in the field of developing relevant information technologies. It should also be recognized that the existing information technologies for managing an IT company and its IT projects practically do not allow using the obtained detailed models for their own improvement. There is a need to develop fundamentally new information technologies for managing an IT company, which would combine the use of the obtained detailed loss models with the capabilities of managing the work of an IT company in a time regime close to real.

Therefore, the following main areas of further prospective research in the field of IT project cost management were proposed to be identified:

– research on the improvement and development of the obtained detailed loss models and the general concept of cause-and-effect management of IT project costs, taking into account the characteristics of IT projects and programs;

– research on the possibility of integrating detailed loss models into existing IS and information technologies for managing an IT company and its IT projects;

– research on the development of fundamentally new IS and information technologies for managing an IT company, including using modern methods and tools of artificial intelligence.

2.8 Conclusions

As a result of the study, the features of the design processes of IS elements in modern IT companies were identified. The situational-consequential scheme of the formation of losses in production as a result of the lack of information was adapted to these features. The adaptation results show that the use of the adapted scheme for estimating costs and making decisions on managing iterations of the implementation of the IS creation IT project in conditions of incompleteness or absence of descriptions of individual IS elements is possible.

Detailed models of losses from the lack of information have been developed if additional processing of the information that replaces is necessary, as well as losses from the lack of information if there is a difference in the cost of the information that is replaced and the information that is replaced. The obtained models can be used with various models and methods of assessing efforts to implement the IS creation IT project.

An experimental verification of the obtained results has been carried out. The course and results of the calculations confirm the possibility of using the adapted scheme and the developed detailed models for estimating losses during the initiation, planning and implementation of the IS creation IT project.

Conflict of interest statement

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

Use of artificial intelligence statement

The authors declare that they did not use artificial intelligence tools in preparing this manuscript.

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