Architectural modeling of a software product for evaluation of labor inputs using practices of system engineering

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Abstract. The present paper proposes a solution to the problem of improving the accuracy of cost estimation at the initiation stage of a project for the development of a software product, the main module of which is a knowledge-based mathematical module. The approach of used system modeling is described, aimed at simplifying the process of analyzing the complexity of the system and improving the accuracy of assessing labor costs. The result of the work is a validation of the proposed approach, performed on the comparison of the expert assessment, the obtained assessment after modeling the system, and actual labor costs.

1. Introduction

The most common problem in project management is the accuracy and adequacy of the expert assessment of the labor costs of product implementation. This problem is caused by several existing difficulties, such as the triple limitation of the project and the atypical nature of the system being developed and the development process itself.

These project design difficulties are discussed in the context of software product development as part of the WFM (workforce management) [1] implementation task. WFM is a system of planning a working time of employees of large enterprises of the consumer sector, providing optimal management of labor resources.

The first difficulty in project management is the triple constraints of project development, which is a state that it is difficult to prioritize the project. In the classical form, triple limitation determines the insurmountable interdependence between the following components: the project scope, resources, time of the project [2]. These parameters cannot be changed alone without the remaining parameters being changed. That is why, in any project, the key question is how to balance and provide the right set of functionalities, considering limited resources and deadlines.

The following difficulty lies in the fact that the main component of the system in question is the mathematical module responsible for:

- forecasting business drivers, which are a quantitative characteristic of the department and determine the number of operations per hour;
- calculation of the workload that determines the number of employees required to carry out activities and provide predicted business driver values;
- optimization of labor costs.
Therefore, without proper knowledge, it is impossible to adequately analyze the complexity of the project at the stage of its initialization and realistically assess the timing and resources for the development of the system. This problem is widespread in non-trivial and atypical projects for which most of the knowledge-intensive components need to be developed from scratch.

These problems lead to the fact that at later stages there are various risks with a high level of manifestation and a high level of potential negative consequences [3]. Also, it is worth noting that the final implementation of the system may often not meet the expectations of the customer, and therefore, as a result of the project, the set business goals will not be achieved.

Based on the described problems that have arisen in the project during its work, it was concluded that without a full-fledged simulation of the system, the expert assessment of the work of the project will be as low as possible and as a result of that, that the number of resources and complexity of the work was not taken into account or were not adequately assessed, that is, the evaluation will not objectively correlate with reality and subsequent implementation of the system is highly likely to lead to unsatisfactory results. A detailed justification for the conclusion will be provided as part of this work.

Thus, the task was set in drawing up a project plan with realistic and adequate deadlines and fixed labor costs, as well as comparing the estimates of work spent on the project with the initial expert assessment. The project plan should be drawn upon the basis of the received system concept, which will contain a holistic description of several system levels, namely business architecture, the requirements of the system customer with the architecture of the mathematical apparatus of the system, and their relationships, which will allow validating the feasibility and correctness of the made architectural decisions.

An additional task is to check the accuracy of the generated assessment of labor costs for the actual work of the project after a certain period, as well as its comparison with the initial expert assessment, made based on the existing experience of the expert and the minimum presentation of the project content.

To solve these problems, this work will use a methodology similar to the practices of Enterprise Architecture. The methodology will be used to obtain a holistic system concept, including the business architecture and system architecture, from which a pool of tasks will be formed for their subsequent evaluation and the formation of a project plan.

2. Methods of modeling

Enterprise architecture is a tool that is designed for a common understanding of the main processes taking place in an enterprise (strategic goals, tactical requirements, basic organizational solutions). [4] As a rule, the principle of many groups of descriptions is used in the design of architecture. This approach is good in that it divides the definition of the system into subject areas, layers, and representations, and offers models for documenting representations in the form of matrices and diagrams. Many approaches have been developed to describe enterprise architecture, defining different sets of description methods.

For a better understanding of this practice, consider some frameworks for working with it:

2.1. TOGAF

The methodology developed by the consortium The Open Group [5], a key feature of which is the representation of the continuum of the enterprise as a collection of blocks - models, processes, architectures that add up to ready-made solutions. The main component of TOGAF is the cyclic process of developing ADM architecture[6].

2.2. DoDAF

This methodology has been developed by the US Department of Defense [7]. The methodology is based on three sets of system visions: operational, system, and technical standards. The fourth view provides a link between all views.[8] This considers the relationships between different levels of the system. This methodology describes the final product, as well as the rules and direction of movement when developing it.
Based on the above frameworks, a general approach to modeling, evaluating, and planning the project was formulated to solve the problems posed.

At the stage of concept formation, it was customary to carry out system modeling within the TOGAF framework using the Archimate graphic language. We will use the practice of DoDAF methodology to identify links between different system levels and views. The DODAF methodology was used to determine the minimum set of views and the principles of their formation to obtain a complete description of the system. The generated model of the approach used is shown in figure 1.

**Figure 1.** Model of formed approach, from system modeling practices to the planning, implementation evaluation.

System concept modeling practices:

- As-Is Business Architecture Modeling (subject area description):
- Fixation of business processes, business objects;
- Selection of metrics;
- Requirements engineering (definition of stakeholders, their needs and requirements);
- Modeling of business architecture To-Be (considering the appearance of the target system);
- Modeling of the information system architecture.

The result of the simulation is a holistic system concept that defines the set of tasks to be solved, supported business processes, functional and structural boundaries of the system.

Based on the concept of the system, the user story (tech-task) of the project is formed and prioritized regarding the requirements and descriptions of architectural solutions. This is followed by an assessment of the implementation of the tasks and the planning of the work on the implementation of the formed tasks of the project.

3. Modeling Contexts
As part of the simulation, an open and independent graphic language was used named ArchiMate [9], this language is intended to develop the enterprise architecture following the specified TOGAF framework. The metamodel according to which the simulation was carried out is shown in figure 2.

![Figure 2. Metamodel.](image)

3.1. Modeling of business architecture As-Is
As part of the study, the processes of the trading network division from the point of view of conducting customer service activities will be considered (the model is presented in figure 3).
Figure 3. Retail Mass Service Process Conceptual Model.

The processes of the trading network divisions include the processes of the main activities for customer service, the fulfillment of business tasks, and administrative processes.

The main activity processes in the presented model are characterized by the following metrics that will be used in shaping the needs:

- the number of transactions (in this case, the transaction refers to the operation of punching one check);
- conversion;
- customer's time in the queue and customer service;
- the total number of staff and the number of personnel involved.

In addition to the main activities of the retail network divisions, there are administrative processes, such as - long-term and medium-term staffing planning, personnel and operational personnel management, accounting for planned absences of employees as part of the formation of the schedule, the formation of a shift schedule (timetables), monitoring the results of customer service activities, managing changes in timetables.

The purpose of administrative processes is to make management decisions that achieve the set business goals by optimizing the main activity of the point (reducing the number of personnel while maintaining the level of service, reducing the time spent on shift planning and change management, increasing the level of conversion, reducing the waiting time for customers in the queue). All these
processes are not intuitive, are accompanied by certain problems, and require the use of modern solutions.

3.1. Requirement Engineering

The next step is to capture the existing problems, needs, and stakeholders themselves based on the business architecture model. Problems are the starting point for assessing the current state of the environment and act as a stimulus to transition to the desired state (the “as it should be” state) [10].

The result of requirements engineering is then identified and captured problems of stakeholders, their needs and requirements, examples of which are presented in Figure 4.

Figure 4. Tracing Problems, Needs and Stakeholders.
3.2. Modeling business architecture To-Be

Based on the formed requirements, the target business architecture is simulated taking into account the appearance of the target system, its services, and business processes, which the system will support.

The target system in our study is the employee time planning and management system, which provides support for the implementation of administrative processes in the field of analysis, forecasting business drivers, planning key indicators, and scheduling shifts (plans).

![Figure 5. Target System Supported Business Process Model.](image)

3.3. Target system architecture modeling

The result of the design is an architectural description - a set of architectural models based on the identified requirements of stakeholders. In our case, we will consider the functional architecture of the system. The general functional model of the system is shown in figure 6.

![Figure 6. Model of the functional architecture of the target system.](image)
The input data are historical business driver data and forecasting parameters. The result of the prediction is a time series that reflects the dynamics of the change in business drivers during a given period from sampling by hours. Based on the obtained time series, specified mathematical parameters, and forecasting parameters (period, methods - forecasting on historical data or using standards), the workload is calculated in man-hours with sampling by hours. The result of the calculation is a version of the calculation in the form of a time series in the section of job categories for a given period. These time series, as well as the operating mode of the department, staffing, mathematical parameters, and planned requests of employees, are used to create a schedule of employee shifts for each day of the selected month for each department being considered.

4. Results of modeling
Based on the received models, a scope analysis was carried out, as a result of which it was necessary to fix the approximate deadlines, resources necessary for the implementation of the modules of the target system. Examples of estimation of labor costs for implementation of system modules are given in table 1.

Table 1(a). Evaluation of labor costs for the implementation of modules of the target system.

| Function          | Module    | Requirement                                                                 | Work Assessment in months per person |
|-------------------|-----------|------------------------------------------------------------------------------|--------------------------------------|
| Repair KPI data   | Data Analysis | T6. The system shall normalize historical data (smoothing emissions and gaps) | 3                                    |
|                   |           | T8. The system shall provide processes of analysis of history and forecasting of business drivers and workload in the following time sections: hour, day, week, month, year; |                                       |
|                   |           | T35. Internal dynamics and external events should be separated in historical data |                                       |
| Forecasting       | Forecasting | T7. The system should forecast business drivers based on historical data with discretization up to 1 hour; | 6                                    |
|                   |           | T18. The system shall provide control of business driver forecast versions (creation, editing, deletion, approval); |                                       |
|                   |           | T19. The system shall ensure mass forecasting of business drivers for selected departments; |                                       |
|                   |           | T20. The system shall provide the results of the forecast of business drivers with the possibility of aggregation across all levels of the organizational structure; |                                       |
|                   |           | T26. The system shall ensure that seasonality and trends are considered when forecasting business drivers. |                                       |
| Resource simulation | Forecasting | T13. The system should calculate the optimal number of staff for a long period in terms of staff positions; | 3                                    |
|                   |           | T33. The system shall perform staffing calculation based on workload calculation and current staffing; |                                       |
|                   |           | T34. The system shall be able to control the versions of staffing (creation, editing, deletion, approval). |                                       |
|                   |           | T21. The system shall ensure that additional business events of the department are considered when calculating workload; |                                       |
|                   |           | T22. The system should provide the ability to calculate workload for units with insufficient data quantity through completion based on information on analog units; |                                       |
|                   |           | T23. The system shall control the version of workload calculations (creation, editing, deletion, approval); |                                       |
|                   |           | T24. The system shall provide mass workload calculation for the selected divisions; |                                       |
|                   |           | T25. The system shall provide the results of workload calculation with the |                                       |
possibility of aggregation across all levels of the organizational structure.

Table 1(b). Evaluation of labor costs for the implementation of modules of the target system.

| Scheduling Verification | Optimization | T1. The average time to calculate the shift schedule must be less than 3 minutes; | 10 |
|------------------------|--------------|---------------------------------------------------------------------------------|----|
| Forecasting Verification | Forecasting Verification | T15. The system should provide the ability to demonstrate the accuracy of forecasts in the past without optimization (as is) so that the model coincides with real data; | 3 |
| Scheduling Verification | Optimization | T30. The system shall ensure that the workload coverage is verified; T32. The system should warn about the presence of violations, conflicts in the work schedules. | 3 |

5. Discussion
As part of this work, a conceptual simulation of the target system was carried out using the enterprise architecture methodology. The simulation results in a system concept that includes a set of architectural descriptions and fixed requirements for the system modules. Based on the concept, estimates of labor costs for the implementation of each individual requirement and a summary assessment were obtained. To validate the results, the initial expert assessment of the project was taken, which was obtained on the basis of the expert’s personal experience in developing similar projects, and the value of the actual work resulting from the implementation of the requirements under consideration for the target system after 3 years from the start of the project. Estimates and actual work are shown in table 2.

Table 2. Value of project estimates and actual work.

| Description | Work in year per human | The implementation period, considering the staff of 3 people |
|-------------|-----------------------|---------------------------------------------------------|
| Initial expert assessment (prior to simulation and system analysis) | 3 year per human | 1 year |
| Targeted peer review (after system simulation and analysis) | 6,5 year per human | 2 years and 2 months |
| Actual work (from 16.07.2017 to 20.07.2020) | 9 year per human | 3 year |
As a result of the comparison of the three values, it can be concluded that the accuracy of the initial expert assessment was significantly lower than the value of the actual work and the estimate obtained from the results of the simulation. The main reasons for this result are:

- subjectivity of the method;
- Unexpected difficulty in shifting a business problem to mathematical logic
- duration of coordination of architectural solutions both with the customer and within the team;
- regular change of requirements (the need to expand the system boundaries without changing the timing and budget of the project) by the customer;
- complexity of system modification in case of functional growth;
- inability to foresee all technical and design risks in advance.

Thus, it can be concluded that the expert assessment obtained based on personal experience in the development of similar systems in complex knowledge-intensive projects significantly diverges from real labor costs. Therefore, the use of this assessment may cause the project to fail. That is why project activities should use system modelling and analysis practices based on generally accepted system methodologies.

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