The Description of a New Model of the Decision Support System for the Projects' Bid Configuration with Multiple Sub-contractors

Tomasz Błaszczyk and Paweł Błaszczyk

***Abstract*—This paper is a summary of work on the construction of the optimization model for decision-makers implementing projects in which the issue is the involvement of external contractors. Using the results of our current works on optimization approaches to the problem of contractors selection with the use of incentive mechanisms we propose outline a comprehensive decision support system (DSS). The practical aim is to enable support for both project owners and contractors in the decision of any sub-contractors at the lower levels of the Work Breakdown Structure (WBS).**

***Index Terms*—Project procurement, bid optimization, multiple-criteria decision-making, buffers management, sub-contractor selection**

I. Introduction

THE problem of the relevant contract type and contractors' selection is a key task of each project owner. However, many scientific papers examine them theoretically or in relation to the specific conditions of the project, it seems that there is still no comprehensive system modeling contracting process at different levels of WBS in general, supporting project's owner and the owners of individual tasks in a project in the making optimal decision from the point of view of the whole process, as well as their particular benefits and risks. Before formulating the concept of the model, we assumed that it must meet the criteria of a mutli-model, as described in the paper of Budziński and Becker [14]. In particular, it should take into account the multi-stage nature of the decision-making process, multi-criteria nature of the issue, number of decision-makers and experts, scalability of the decision problem flexibility of decision variants, and linguistics of date.

In The Project Management Body of Knowledge (PMBoK Guide) PMI [19] (current and older editions) delivered a complex, systematic approach to project management processes where the project procurement and contracts management issues are considered but not comprehensively described in terms of input and output data with an indication of effective optimization methods. In our paper [10] we suggested to develop this approach by introducing bid configuration process.

In the literature, there are many well-known approaches and opinions on the ways to select contractors and conclude contracts for individual projects scopes. Ranging from general guidance to choose the form of the contract (as described in Turner and Simister [20]), by indication of the specific selection methods (such as Holt [16]) until ready proposals of systems supporting sub-contracting in certain types of projects (eg. in the paper of Arslan *et al*. [1]). Almost all the authors emphasize that the selection of the project contractor (and, of course, possible sub-contractors) is a problem of multi-criterial nature. In the modern approach to procurement management in projects it is noticeable to move away from total transfer of risk to the contractors for the partnership approach, taking into account the risk premium for both parties and trade-offs allowing the more flexible development opportunities for the assessed criteria. Lack of this flexibility meant that the need rigid to adapt to customer requirements caused an final increase in project costs. Of course, such solutions are theoretically and practically effective (eg. Bubshait [13], Lahdenperä [17], Boukendour and Hughes [12] or Missbauer and Hauber [18], but not always allowed in all legal environments (see Bochenek [11]).

At the core of our proposed methodology lies the concept of critical chain by Goldratt [15] supported with the idea of the cost buffer with incentive fund described by Błaszczyk and Nowak [2]. This approach was formalized by Błaszczyk *et al.* [3] with introducing the matrix of factors influencing standard projects' evaluation criteria of duration and cost, and by developing work effort estimations for each projects' activity by Błaszczyk and Błaszczyk in [4] for deterministic case, and Błaszczyk *et al.* in [6] for fuzzy estimations. Models supporting the decision-maker in the role of general contractor was described by Błaszczyk and Błaszczyk in [5] for the most general case and in [7] for specific expression of fixed price and cost-plus contracts and more broadly in [8]. The general outline for the DSS realizing this approach procedures was submitted by Błaszczyk and Błaszczyk [9].

II. Objectives

Decision support system supporting procurement decisions in project planning has in its intended form a new e-service

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available to users of the global network, involving the use of an electronic agent system for matching potential business partners defining the needs of the project undertaken and offering tools for multi-criteria assessment of potential bidders to select the most favorable proposal or a decision of a production of product / service. The main objective of the project is to support the decision in projects through:

- To create a tool to support the selection of the main contractor specific offer in the conditions of the plurality of evaluation criteria.
- To create a tool for supporting the decision of an own production or buying a service or product
- To provide channels of communication between the principal contractor, subcontractor, and the project owner to the project
- To create of a forum for contractors expanding area of business entities from the local market to the national / international
- To collect data about the preferences of potential contractors in relation to the selection of patterns and schemes and analysis of potential offers.

III. Users

In general, all users of the system can be divided into two main classes: internal and external users. To external users we include all those to whom the proposed service is transferred as a optimization tool, while the internal users we include administrators and all analysts who use the information from the database system and preparing the appropriate analysis and reports. The system is to provide an innovative service consisting in the main outline, the possibility of multiple-comparison, the selection of contractors, selection of offers, Make-or-Buy analysis and the completion of the transaction. The system in its assumptions should be the general system, without taking into account the particular specifications of any particular industry. Potential external users of the system will in fact project owners, main contractors, their subcontractors. Due to the characteristics of potential customers in the system will be defined following roles: the role of project owner, the role of the main contractor and sub-contractor role. Customers service can perform several roles simultaneously in the system. For example, the main contractor of the project may wish to delegate the implementation of some tasks to other subcontractors, thereby form a new project and will be also the owner of the project. At the same time a subcontractor in one project can act as the project owner or contractor in different projects. The system provides the possibility for users lists of verified contractors.

The owners of the project are representatives of stakeholders in the implementation of a specific project. In view of this group of users it is assumed that they tend to choose a few (dozen) potentially interesting their offerings and technically uncomplicated (not needing specialized expertise, knowledge of the methodology or decision-making tools) to compare these offers, assuming that the criterion of assessment is not only price of a given model but also other defined by its performance. This group of users can also expect certain facilities for communicating with a potential principal contractor (the sender offers) in order to carry out the same transaction. They also have full access to the project's WBS and all its parameters. Principal contractors are parties interested in the implementation of a specific project. They can send offers for the project. They have no effect on the defined project, but during implementation of the project have the opportunity to analyze the make-or-buy and make a decision about self-realization of tasks or to outscource several tasks. In this way they can create new sub-project output. Subcontractors that the entity interested in running a particular task create and send offers that are being analyzed and evaluated by main contractors. Internal users of the system, besides administrators responsible for the proper functioning of the system, data analysts are mainly concerned with qualitative and quantitative analysis of a set of database accumulated by the system. They play a significant role in the process of improving the operation of analytical and optimization algorithms and external analytical services. From the point of view of the system they are the only actors downloads data, not generating any input, but burdening the database system generated queries.

IV. Constraints and assumptions

Identification and analysis of the functional requirements of the system was carried out on the basis of the scenario method with the use of systems structures and behaviors modeling. Due to the large number of system functions the behavioral model of the system is presented in a hierarchical use case diagrams, according to the top-down method. In this article, we present only the most important functional requirements of the designed system. The use case diagrams have been prepared in accordance with the UML 2.4 specification. In order to define the limits of the product and preparing the model of the first level, first we identified all the actors involved in the operation of the system. There are basic users defined in the previous section and subsystems and tools that interact with the host system. To the first group of actors we include: Customers directly offered by the e-services, namely:

- Project Owners (PO) – institutional client interested in the implementation of the defined project WBS.
- Principal contractors (PC) - institutional clients interested in the duties of the main contractor.
- Sub-contractors (SC) - Institutional clients bidding on individual tasks in the project.
- Data Analysts (AD) - experts in qualitative and quantitative analysis of a set of database accumulated by the system.
- System Administrators (ADM), supervising the maintenance of business continuity and security systems and implementing basic administration and office work based on the results of the system (eg. invoicing customers).

The group of subsystems and tools consists:

- e-mail system (PRS) – a mail system of client or analyst participating in the process of registration and correspondence.
- analytical and reporting system (SyAR) - Satellite subsystem performing analyzes of substantive content

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databases and how they search for statistical processing and report generation market analysis.

- the analytical engine optimization (SiAO) - Satellite subsystem performing formal analysis of bids, offering customers preferences analysis tools and decision support (building ranking of bidder).

V. Functional Requirements

For such defined the main actors the first level use cases diagram defined for these users of the system include:

- Viewing information about the system and implemented solutions - available to every customer, with information about the principles of operation, descriptions of used tools, manuals, tutorials, training materials, promotional, etc.
- Browse and search for listings - the service available to every customer in being able to view available jobs and generating sales of database queries to search listings meet both predefined and asked the customer criteria.
- Preferences analysis, make-or-buy analysis, evaluation of bidders - the group of use cases are available for registered users, allows you to specify criteria for evaluation of bidders, analysis of their significance and determine the ranking of bids, and also an analysis of make-or-buy.
- Account Management - a service available to the registered customer, giving the opportunity to:
  - Create, review, edit, and print projects
  - Import and export projects to / from most popular programs including project management tools such as MS Project
  - The ability to integrate tasks with MS Outlook calendar
  - Create, review, edit, and print inquiries
  - Create, review, edit, and print listings (offers portfolio)
  - Create, review, edit, and print a list of qualified contractors
  - contacts between the general contractor and sub-contractor and between project owner and general contractor
  - Review the history of contacts with other service users
- Extraction and processing of the data - a service available to DA users allowing for access to the database and offering relevant tools to generate complex queries and basic statistical analysis.
- System Administration - the group of the use cases of the appropriate system administrator (ADM). Describes services related to the maintenance, data administration, preparation of reports for the administration department.
- Login and registration - use cases relevant to all service users allowing for the registration of and access to individual accounts (in which additional services are implemented).
- Profile Management - use cases relevant to all registered users allowing users to edit and modify profile including personal data, corporate, managing access to verified bidders lists, browsing history, payments etc.

Identify the main actors and use cases possible to determine the relationship between them (in particular association) and to prepare a use case diagram of the first level, which is the general model of the system (see Fig. 1).

VI. Non-functional requirements

A. Ergonomic Requirements

From the point of view of ergonomics of use the system should be intuitive and functional UI and menus. The

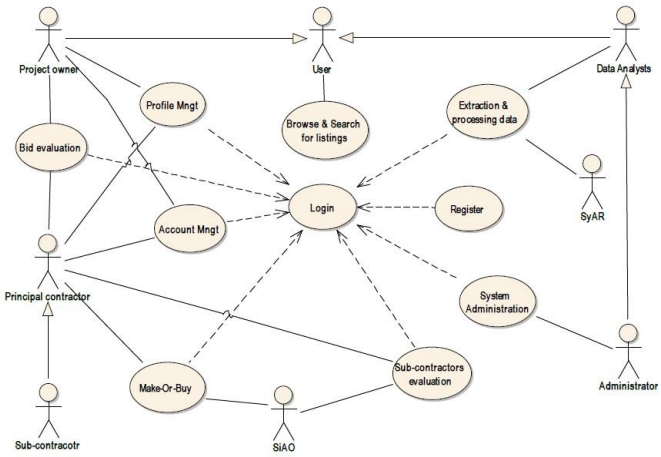

Fig. 1. General use case diagram of the system

product should be easy to use even for people with minimal knowledge of information technology, substantive (in the field of decision-making). They should use vocabulary and symbolism fully understandable to the average Internet user. All technical aspects should remain hidden from the user. Verification of compliance with these requirements should be the maximum permitted time in which the user begins to move smoothly through the site. This time should not exceed a few minutes. The user must have the ability to display and expose these elements, which is the most interested, and hide those that are unnecessary to him (eg. Free to modify the scope of information shown in the listing tables). The criterion for this requirement is the functionality of the software for all users allows for appropriate modification of the display of individual functional elements (menus, table formatting, etc.)

B. Performance Requirements

A very important group of non-functional requirements are performance requirements. They concern the critical issues that affect the evaluation of the system by users and willingness to use the site in the future. These requirements will mostly refer to the maximum time access to the site and implement basic and advanced analytical operations on the system. Depending on the type of users we can distinguish the following performance requirements. The basic performance requirement is implementation of all operations related to the service information and a searchable database standard time similar to similar operations carried out in the

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most popular websites. Another requirement concerns the duration of the performance of the analytical operations carried out by the system. The make-or-buy analysis, evaluation of bidders and building preferences must be carried out in or near the time the regular site calls to the database. Operations reporting and data analysis carried out by the system SyAR the needs of users, depending on the complexity of the analysis should be preceded by adequate information about the estimated waiting time. Results of the analysis and reports should be available within the user accounts and email the information about their availability. These reports should be available to users in no more than 15 minutes of an order for the report. The requirements for precision and accuracy of the calculations should be met 100%. Unacceptable are any calculation errors and the accuracy of the statistical calculations and optimization algorithms should be considered sufficient level of interpretation to two decimal places. The requirements apply statistical analysis of their compliance with the methodology of multi-descriptive statistics and statistical analysis. The analysis must be made on the basis of the above basic methods. by statistical departments. Reliability to the system requirements are extremely rigorous. Due to the realization of paid services and the specificity of their benefits online system should be able to work 24 hours a day, 365 days a year. Maintenance work must be performed during the service operating at lower intensity (in the early hours of the morning) and disable access to services cannot be longer than 4 hours. Any system failures - extremely undesirable - must be removed immediately, within fifteen minutes after the occurrence through the upload current backup.

C. Requirements for the working environment

The proposed system will operate in a cloud environment (eg. Amazon AWS). Due to the required performance and safety of the system should be implemented in Java EE in accordance with the template MVC and using Spring framework. The system should be modular. The analytical module responsible for carrying out all the analyzes provided for in the decision-making system and a web module for communication with the user should be a separate, independent units. For reasons of performance and ease of scaling, as the database engine should be considered NoSQL database for example Redis. Communication with the database should be done with the use of the buffer, the size of which shall be determined by the administrator. The designed system should take into account the specific nature of the server on which it is installed. You should also decide on the type of cloud environment (IAAS/PAAS). The detailed audit of server security and functions must be made. On this basis, it will be carried out properly configured the service. It must be ensured the possibility of continuous access to the site 24 hours a day, 7 days a week. Required is to create regular backups of both service applications and the database. These copies will be stored both on a separate server and data storage media deposited in service owner premises.

D. Safety requirements

Access to all functionality of the service, including accessible for every user the public area of the site must be recorded in the logs. There should be stored such information as user data including IP, date, time, time spent on each page, executed commands. Access to the paid part of the site will be possible after completion of the registration process and user authentication. The data in this particularly sensitive personal data must be adequately protected. Stored passwords must be encrypted and access to the database strictly limited and monitored. Each incoming data from the user to the site must be monitored and archived. Then, before using the data, they must be subjected to a process of filtration. In particular, it is important to ensure the safety of the service through the use of appropriate software security that is implemented at the level of program code. Lack of adequate protection could lead to a break because both applications and the attack on users using it. Firstly there should be implemented safeguards against the risks associated with the injection and execution of malicious code. In particular they should be implemented protection against SQL injection and Cross Site Scripting, Cross Site Request Forgeries, injection system commands, injection newline, transfer malicious code to a function interpreting and performing Java code modification path or file name processing hostile script from a foreign server, a modification of the names of dynamically created variables or functions. The second type of threat that must be taken into account during implementing the service are the threats arising from the manipulation of parameters. In particular, the system must be safe to attacks involving the manipulation of demand chain, form fields, headers, and HTTP request COOKIE values. Each data must necessarily go through the process of filtration. The parameters and the degree of data filtering restrictions must wash ascertainable by the administrator. The next type of security is protection against unauthorized access to resources and the disclosure of confidential information. In particular, mechanisms must be used to prevent leakage of information, including through block error messages and system messages, block access to debug commands, not to place comments in the HTML code. The problem of information leakage can be seen also in another aspect. It concerns the disclosure of hidden or confidential data, files or documents, which themselves may be subject to attack or they may contribute to its execution. The problem of unauthorized access to resources, which should remain confidential, mainly due to the fact that they are placed under the document root of the web server. This way you can access them directly by typing the exact URL in a browser window. Elements of the operating system that must be protected are: hidden files, backups and temporary files, source files. The application must also be protected by the so-called Google Hacking. Internet search engine Google is now one of the largest available on the market. In its indexed resources are millions of links to Web sites around the world. In addition, this tool has a number of options that allow for comprehensive and advanced search. It can be, and often is, used by crakers. Thanks to a crafted queries attacker can get a lot of useful information on the site. In addition, it must be prevented disclosure of source files. Disclosure of source files and other resources stored locally on the server is made possible by a technique called directory traversal. This attack are prone to all scripts using template files or in some other way of referring to files on the server. This attack runs through manipulation of the chain demands. There must be used appropriate mechanisms for authentication and secure user session management. The system must be secure to a dictionary attack, strength, power

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inverted attacks and attacks involving the interception of the session, the presumption session. They must be implemented adequate procedures to verify the password in terms of its strength and blocking access to the account after crossing the threshold amount of incorrect logins. Shared must be logged via SSL.

E. Legal Requirements

Determination of the legal requirements for the system requires legal consultation in many aspects of operation of the service. They cover both the data protection rules, as well as issues related to cost accounting principles services offered by the system, the principles of free use of the system, the transmission of information between interested parties, contract, etc. In this respect, it is necessary to make a professional legal work.

VII. The Process of Contract Acquisition

As we described in section III user of thie service can have one of three roles: the project owner, main contractor or sub-contractor. The owner of the project after logging defines the project. On the basis of input the decomposition of the project into tasks must be done. One must define the WBS, specification of works and Network Diagram. One of the functionality of the system is the ability to import project from popular project management support tools including e.g. MS Project. For such a user-defined project user can perform the Make-or-Buy analysis. As a result of this analysis user shall decide which of the tasks in the project will perform alone, and that will be outsourced. If the user is going to have some work performed for a sub-contractor he can use the service for the quoting process and define essential terms of the contract and then send an inquiry. Such an inquiry can apply to both requests a quotation, request for proposal and request for bid. Inquiries can be sent both to contractors who are on the list of verified contractors as well as to all other in the database service. If a potential sub-contractor is not on the list of pre-qualified performers user has the possibility to carry out the process of qualification of subcontractors. Positively verified subcontractor may be entered on the list of performers verified. The potential subcontractor received the inquiry and prepares a response. He introduces its parameters to the service. In addition to the introduction of appropriate offer parameters such as price, deadline, he also has the ability to attach additional files in pdf format. Before bidding contractor shall conduct its own analysis of Make-or-Buy as a result of which it may decide to execute that task yourself or order it to another sub-contractor. Then he has the role of project owners or main contractor. The user defines the system a new project under the terms received from the prime contractor. The main contractor after receiving bids from potential sub-contractors shall analyze the bids and can carry out the qualification procedure for sub-contractors. During this analysis, the main contractor can determine the offer as satisfactory or unsatisfactory. For listings of pre-identified as satisfactory assessment process of bidders and selection of subcontractors (see [5]). In between commissioning and the bidder shall negotiating contract terms, including the election of contract forms. At any moment, the main contractor has the ability to opt out of commission subcontractor work and decide to perform the task on their own. A detailed process description can be found in [10]. At the Fig. 2 we describe the schema data and method used by decision makers.

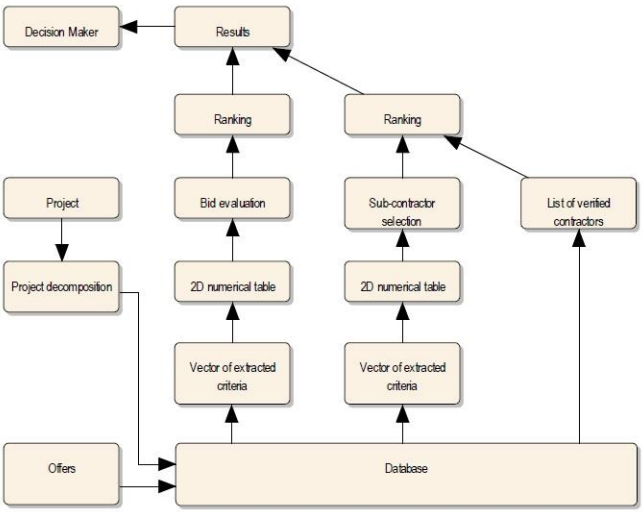

Fig. 2. The schema of data and methods used for decision making.

VIII. Conclusion

In this paper we presented an outline of the DSS dedicated to supporting the procurement and contract management processes for different types of projects. It uses a formalized record of critical chain concept in multi-criteria extension using the influence matrixes. Its versatility allows it to be used in web-version and individual users can optimize both the selection of contractors and the configuration prepared by themselves tenders, which should allow to obtain better performance of the entire project, including all levels of WBS. In the content we pointed references to the detailed methodological solutions contained in our other works. A further stage of the system preparation will comprise its programming and testing.

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