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SELECTED METHODS OF COST ESTIMATION OF ERP SYSTEMS' MODIFICATIONS

1. Introduction

The problem discussed in the article concerns project managers representing suppliers of ERP-class (Enterprise Resource Planning) software [1], who negotiate with end clients. In the course of negotiations the parties reach a conclusion that the organisation of processes in a company does not overlap with the processes supported by the offered software [2]. At this stage they face a problem of valuing the costs. ERP system is an integrated IT solution that covers virtually all areas of enterprise's activities [3]. The discussions concerning implementations cover such important features as system vastness and openness to changes [4].
System modifications involve redefinitions and broadening the processes supported by IT solutions. Standard set of major ERP system functions is similar for all the suppliers. The differences concern additional functions characteristic for various business lines. It is important to define standard functionalities as they constitute a subject to consider further modifications [5].
The literature provides a number of analyses concerning the costs of IT systems (costs of errors, maintenance etc.) [24] or examples of mistakes in individual methods of software valuation [6]. However, there are no reliable results concerning the analyses of cost estimations for IT system modifications, which can be found in the present article.
The first of the analysed cases (project no U03333) concerns a production company in energetic business, whose board decided to implement an IT solution due to problems in production management (errors in deliveries, manufacturing errors). At the very initial stage of negotiations IT system provider noticed processes specific for this particular client in making orders, production and order completing for deliveries. The client expected the system supplier to quote the price of ready-to-use solution at the end of trade negotiations.
The second case (project no U1130) concerns a company in the business of manufacturing epoxy resin which had been using ERP system since 2005. Despite regular system maintenance, the old technology turned out to be a barrier for future development. IT system provider had to determine the costs of migrating the set of company-specific functionalities to the current standard version of the system. The price was the basis for making decision about project implementation.
In the third case (project U02142) the managers of the company producing metal constructions realised the need to control the work of production departments by following the products at all production stages. Alike in the previous case, old ERP system, which had been used since 2004, was a barrier. The change of system version and transferring the modifications opened the way for further development of the system. The price was the basis for making decision about project implementation.
In general, all three cases concern medium-sized manufacturing companies with ERP system with known functionalities implemented or under implementation. In each case the set of client's additional requirements, which differ from standard functionalities, is known. The methods of software evaluation are also recognised. The provider uses one IT system and one programming environment (homogenous system). The design and programming teams consist of up to 10 consultants. Each project lasts less than 12 months. The article attempts to find answer or state that it is impossible to answer the question if it is possible to evaluate precisely the costs of modifications of the ERP system for a medium-sized company.
The present article contains, in Chapter 1, the description of software pricing methods. Another chapter is a short description of evaluation processes in three projects implemented in 2010-2012. Chapter 3 presents the solutions resulting from the effects of analysing pricing methods used in the projects and the real costs the companies had to spend.

2. Methods of pricing costs of ERP system modifications

The methods facilitating the pricing of software development are known and described [6]. Only two of them are described with algorithms (COCOMO, function point method), whereas other consist of only "soft" guidelines. The use of algorithmic methods in initial stages of IT solution implementation is difficult. There are no project documents that contain the data necessary for estimating algorithms. Even though literature quotes examples of using algorithms at early stages of IT projects [7, 8], the practices of IT software suppliers show that non-algorithmic methods are used as quicker (i.e. cheaper) and easier to use. Subsequent part presents the descriptions of methods which were used in the discussed cases. The literature gives a number of examples of using estimation methods for IT projects: from the statement that any techniques should be used, depending on the case to case basis, to the step-by-step approach [9].

2.1. Summing, computing, evaluating

The method concerns searching analytic documentation or other to find any quantifiable areas, e.g. requirements, functions, uses, stories, function points, reports, windows, database tables, classes. The model of the method stems from COCOMO software evaluation methods [10]. Each of the identified objects can be attributed with a constituent (of cost or time), The method can be used at every stage of software development or modification.

An example of its use can be the valuation of developing a sales reporting module. If the authors managed to select the premises, such as SQL queries, interface windows, users and printouts, it is possible to define a unit cost. Thus, one can evaluate the costs of developing the whole module, as presented in Table 1.

2.2. Individual expert evaluation

The method of valuation by individual expert estimation is the most frequently used method, not only in software development [11], but also in other IT enterprises such as implementations and modifications. The research conducted in USA in 2002 showed that as many as 72% of the valuations are done with this method [12]. The method is typically used together with decomposition and reconstruction methods. Initially, it concerns selecting experts with appropriate experience and knowledge for a given project task. In another stage the experts evaluate the assigned tasks. In order to limit the valuation errors, the method was modified by multiplying the valuation tasks. Such a technique, called PERT (Program Evaluation and Review) [13, 14], involves analyses of the most optimistic, the most probable case and the worst case. The expected value of estimation has the following form:

$$f(x) = \sum_{i=1}^{N} (Cp(x_i) + 4 \cdot Co(x_i) + Ck(x_i))/6 \qquad (1)$$

or considering experts' inclinations to lower the price:

$$f(x) = \sum_{i=1}^{N} (Cp(x_i) + 3 \cdot Co(x_i) + 2 \cdot Ck(x_i))/6 \qquad (2)$$

where:
Cp – the most optimist value of the i-th task,
Co – the most likely value of i-th task,
Ck – the most probable value of i-th task.

Valuation of sales reporting module can be an example of the method. If the authors managed to select the premises, such as SQL queries, user interface windows, and printouts, the expert can estimate the most optimistic, the most likely and the least favourable amount of work load. Then, one can determine the costs of programming work on the module (additionally, considering the inclination to lower the evaluation), as presented in Table 2.

2.3. Group expert evaluation

The method is most frequently used at initial stages of IT projects in situations of high level of uncertainty about requirements. It involves presenting the same range of work to more than one expert. In unstructured version of the method (group review) the experts decide about the valuation or its range as a group. In a structured version, called Wideband Delphi [15, 16], experts' work is done in a formalised way and its result is a scoring evaluation.

2.4. Decomposition and reconstruction

It is a popular method due to its intuitiveness and universality, concerning a decomposition of the object into a number of parts. The method of division is arbitrary and depends on project specifics. Consultants frequently do evaluation with Work Breakdown Structure (WBS) method. Having done the division, the parts of objects are estimated and undergo further division with the same or other method. A detailed description of decomposition method according to WBS can be found in literature [13, 17, 18, 19]. One example of this approach can the evaluation of IT system version change. The works can be decomposed in the manner presented in Table 3.

2.5. Evaluation by analogy

The method concerns dividing the project into components that already exist in a completed project. Evaluating the selected parts, one may calculate the ratio of two projects' sizes (new and the completed one). Knowing the relations between the sizes and the costs of the completed project, one may estimate the value of the new project. One example of this method is presented in Table 4.
Average multiplication index for the above example is 0.57. Knowing this result and the value of the completed project, one can estimate the value of works.

2.6. Valuation based on substitution

Alike the previous method, this method requires the knowledge of previously completed organisation of standard

Summed elements	Number of objects	Estimated cost per object [h]	Value
SQL queries	14	6	84
User interface windows	8	3	24
Printouts	6	6	36
		Total	144

Tab. 1. Example of coast estimation with the method of summing, computing, evaluating

Evaluated work	Most optimistic value [h]	Most likely value [h]	Least favourable value [h]	Calculated value
SQL queries	45	81	108	84
User interface windows	14	22	32	24
Printouts	25	33	45	36
			Total	144

Tab. 2. An example of estimation with individual expert evaluation method

No	Range of work	Estimated value [h]
A.	Preparatory work:	
A.1	- software installation	
A.1.1	- application server software installation	5
A.1.2	- server database software installation	4
A.1.3	- user software installation	14
A.2	- database import	
A.2.1	- export from "old" verification system	8
A.2.2	- import to the new system	11
A.2.3	- reconstructing indexes and data verification	16
A.2.4	- back-up copy parametrisation	2
B.	Modification movement:	
B.1	- modification movement in the area of finances	34
B.2	- modification movement in the area of personnel	21
B.3	- modification movement in the area of production	120
C.	Trainings:	
C.1	- financial departments	16
C.2	- HR department	16
C.3.1	- hull production staff	4
C.3.2	- wind station staff	4
	Total	275

Tab. 3. An example of valuing with de construction and decomposition method

Parts of decomposed project	Completed project [h]	New project (estimation)[h]	Multiplication index
Database table	60	42	0,70
User interface	43	18	0,42
Raports	54	32	0,59
SQL queries	85	54	0,64
Basic classes	28	14	0,50

Tab. 4. Example of calculating multiplication index in evaluation by analogy

objects. Depending on the version of method, the objects can be grouped differently. For example, Putnam [14] and Humphrey [20] selected classes of objects: very small, small, medium, large and very large. Another method of classifying the objects is a standard component method [6] used to valuate object software. The division can then be as follows:
– dynamic WWW websites,
– static www websites,
– data tables,
– reports,
– business rules.
If the organisation of information system supplier uses the extreme software or close to Agile methods [21], so called "stories" might be a standard element.
Then, the groups of objects are attributed with average cost values, e.g. number of lines of code (LOC), working hours or days. The objects from a new project must be classified in the same manner. Then their sum can be calculated.
An example of such an approach can be the project of white goods' sales. Cost estimation is presented in Table 5.
The supplier determines average cost of works in a given class, e.g. a cost of building one static website – 2 working hours, on the basis of previous historic data. In a new project the works are attributed with appropriate classes, e.g. dynamic websites – 5 pcs., reports – 9 pcs. Then the old objects are substituted with the new ones.

3. Selected cases of IT projects

3.1. Project no U03333

Company description
The company in energy business supplies construction businesses with the devices operating at medium and high voltage. The production concerns assembling the ordered elements which are purchased from suppliers or subcontracted. The production is only upon client's order. In a month the company makes c.a. 500 unique orders (up to 10 pieces in an order).

Source data for evaluation
Prior to the stage of negotiations, ERP supplier made a pre-implementation analysis. The analysis concerned the areas in which specific processes were anticipated, i.e. logistics and production. Differential analysis with relation to the standard IT solution was made by the supplier. Therefore, analytic documentation included:
– description of processes that were not available in a standard version,
– descriptions of functionalities that were different from standard.
The following problem areas were selected (numbers from the analytical documentation):

Standard classes of components	Average value of costs[h]	Number of objects in a class	Value of costs [h]
dynamic WWW websites	7	5	35
static WWW websites	2	18	36
data tables	7	16	112
reports	5	9	45
business rules	12	5	60
		Total	288

Tab. 5. An example of valuation by substitution

(W_01) – orders of supplies made directly on the basis of production orders,
(W_02) – sharing supply orders between the preferred suppliers,
(W_03) – managing additional information on the products needed in technologies,
(W_04) – managing technology parameters with inheriting them by inferior order,
(W_05) – preparing technological documentation for subcontractors,
(W_06) – completing a final product from many production order.

In the above groups over 30 requirements were identified. Most of them required the change of data structure by adding fields to the existing tables or making new tables.

Cost evaluation methods

Specifying the requirements and dividing them into problem areas, the analytic document suggested the use of decomposition and deconstruction methods in the first stage. The evaluation was done by three consultants appropriately assigned into the problem groups: production logistics and sales. On the basis of the descriptions in analytic documentation, the consultants decomposed further requirements. For instance, the requirement of managing technology parameters W_04 was decomposed into:

W_04_01 – managing acronyms and parameter descriptions,
W_04_02 – managing the dictionaries of parameter values,
W_04_03 – translation of order parameters between subordinate orders,
W_04_04 – controlling material limits with consideration of parameters

The measure unit for costs evaluation is a working hour. Some fragmentary requirements were estimated by analogy. For instance, requirement W_04_03 was estimated on the basis of a similar requirement that is present in the standard version. The current requirement was the extension for the solution, therefore, multiplication index was adopted at 0.3. Other requirements were estimated with:
– method of individual expert evaluation, provided the evaluated elements do not exceed 40 working hours,
– Wideband Delphi method (collective expert evaluation) engaging additional consultants, provided the evaluated values exceeded 40 working hours.

The works on requirement evaluation absorbed over 20 working hours and engaged 5 consultants. The total value of works necessary to complete the requirements was 332 working hours. The implementation was scheduled for three consultants for three months.

Implementation

The works were completed within 3 months and submitted to client's final tests and acceptance. Up to then the total amount of work was 392 working hours. The cause of underestimation was the difference between client's and consultant's understanding of requirements. During the tests, faults which could not have been indicated before were revealed. 5 major and 20 minor errors were removed. The cost of implementation was additionally increased by 85 mending working hours. The data of releasing the system to work, together with mending the errors was 6 months. The cause of errors was the interaction of new functions with the existing standard system processes. Real time-consumption of works in comparison to the estimations, depending on the function area and method of estimation was presented in table 6. The first method of estimation, decomposition and reconstruction, was ignored because it was present in all cases of evaluation.

3.2. Project no U01130

Company description

The company makes products from epoxy resins for energetic and ship building industries. ERP system was used and maintained since 2005. The project involved installation of new system version, moving the modifications, data import from previous version and the implementation of new modules:
– multidimensional analysis in logistics and finance,
– equipment management (tools, uniforms)
– CRM.

The supplier held the documentation of modifications since 2005.

Source data for evaluation

Prior to the stage of negotiations, ERP supplier made a preimplementation analysis. In the analytic session the necessity to migrate the modifications to the new version was verified. The modifications of old version concerned:
– changes in standard function,
– additional functions,
– additional printouts and reports.

Out of 65 requirements and 42 reports, 38 modifications and 34 reports were qualified to migration. Additionally, the requirements for equipment management were documented.

Area of modification	Evaluation method	Estimation [h]	Implementation [h]	Estimation error	Standard deviation of errors
Logistics	Expert valuation	34	43	26%	32%
Production W_03_03	analogy	114	225	97%	143%
Production – other minor modifications	Expert valuation	48	55	15%	56%
Production –other major modifications	Wideband Delphi	91	85	-7%	18%
Sales	Wideband Delphi	45	69	53%	64%
	Total	332	477	44%	-

Tab. 6. Comparison of estimated and real costs in project U03333

In this case the analysis showed differences from the standard solution. The documentation of requirements contained:
– the requirements which must be reconstructed in a new version, divided into:
– requirements in logistics,
– requirements in production,
– list of procedures in data transfer,
– descriptions of functions which are different from standard ones in the area of equipment management.
The client decided to use the remaining two new areas (multidimensional analysis and CRM) in standard versions. Thus, the documentation did not cover the requirements concerning these areas.

Cost evaluation methods
Alike in the previous example, analytic document specified the requirements, divided them into problem areas and suggested the use of decomposition and reconstruction method. At this stage four consultants were assigned to problem areas: logistics, production, data transfer, equipment management.
When necessary, the consultants made further decomposition of requirements by estimating on the basis of the descriptions included in analytic documentation. The unit of evaluation was a working hour. The requirement concerning modification migration was made with a combination of expert evaluation and the analogy method. In the first stage a random test for five requirements was run. For these requirements, evaluation with expert method was conducted. The results were compared with the historic data of modifications implemented since 2005. In this way average multiplication index was calculated, what is illustrated in Table 7.
The index was used to make estimations in the method of analogy to other requirements concerning modification migration. The requirements concerning the reports of migration procedures were estimated in summing, computing and evaluating method. The cost of making a report was estimated at 3 working hours per report. The information about real costs of making similar reports in a different project was used. The procedures of data migration was estimated at 9 working hours per each, in accordance with individual expert evaluation. The cost of changes in equipment was estimated with individual expert evaluation method, after decomposition was run.
The works on estimating the costs of modifications absorbed over 80 working hours and engaged 6 consultants. The total estimated value of works necessary to compete the requirements was 789 working hours. The implantation stage was scheduled for three consultants for the period of 6 months.

Implementation
The works were completed in 6 months and the system was submitted to the client for tests. Up to then, the cost was 680 working hours. During the test, users identified faults which had not been pinpointed during internal tests. 8 major and 30 minor errors were removed. The cost of implementation was additionally increased by 45 working hours of maintenance works. The cause of errors was the disturbance of data due to modifications in standard processes.
Real time-consumption of works in comparison to the estimations for each function area and evaluation method is presented in table 8. The first method of estimation be decomposition and reconstruction was ignored because it was present in all cases of evaluation.

3.3. Project no U02142

Company description
The company makes steel products for agriculture and the constructions industrial halls. ERP system was used and maintained in the company since 2004. The project covered installation of new system version, migration of modifications, data import from previous version and implementation of module for remote warehouse management with the use of data collectors. The system supplier owned documentation of the implemented modifications.

Source data for evaluation
Alike in previous cases, prior to negotiations, the system provider made a pre-implementation comparative analysis. In the analytic sessions the need to migrate to a new system version was verified. 13 requirements were qualified to migration and 9 new requirements were identified. All the requirements concerned the area of production (W_1 to W_22) and logistics (W_23 to W_30) (symbols from analytic documentation).

Cost evaluation methods
Alike in two previous examples, analytic document specified the requirements, divided them into problem areas and

Symbol of requirement	Historic value [h]	Estimated value [h]	Multiplication index
L.4	9	5	0,56
L.12	28	12	0,43
P.6	43	25	0,58
P.9.	8	6	0,75
P.17	12	8	0,67
		Average value	0,60

Tab. 7. Example of calculating multiplication index in project U01130

Area of modification	Metod 2 / metod 3	Estimation [h]	Implementation [h]	Estimation error	Standard deviation of errors
Modifications in logistics	analogy / Expert valuation	304	358	18%	23%
Reports in logistics	Summing, computing, evaluating / substitution	63	55	-13%	21%
Modifications in production	analogy	165	197	19%	28%
Reports in production	Summing, computing, evaluating / substitution	39	43	10%	21%
Data transfer procedures	Summing, computing, evaluating / Expert valuation	173	155	-10%	35%
Equipment management	Expert valuation	45	56	24%	31%
	Total	789	864	10%	-

Tab. 8. Comparison of real and estimated costs in project U01130

suggested the use of decomposition and reconstruction method. Requirements W_1 to W_8 were decomposed, whereas requirements W_9 to W_30 were not large enough to be divided. The decomposed requirements were evaluated with summing, computing and evaluating method. The following objects were summed: entities, business rules, reports. Then, analogically to historic data the costs of each element was evaluated. Other requirements (W_9 to W_30) were evaluated with individual expert method. In case of modification migration (W_9 to W_22) the method of analogy was used but the multiplication index was not determined. Expert verified the evaluations with corresponding historic data. Depending on their experience and a given requirement, they used multiplication index of 0.3 to 0.7. The works on estimating the costs of modifications absorbed over 20 working hours and engaged 2 consultants. The total estimated value of works necessary to compete the requirements was 456 working hours. The implantation stage was scheduled for three consultants for the period of 6 months. The unit of cost estimation was a working hour. It was anticipated that additional requirements will appear, which might be completed in a period of time shorter than a working day.

Implementation

The works were completed in 3 months and the system was submitted to the clients for tests. Real time-consumption of works in comparison to the estimations for each type of work and evaluation method is presented in table 9. Alike in previous examples the method of estimation by decomposition and reconstruction was ignored.

Even though the error in migrating W_9 to W_21 functions was only 3%, the errors in other requirements were much more significant and standard deviation [22] was 79%. For the evaluation of new modifications (W_22 to W_30) standard deviation was slightly lower and equalled 74%.

5. Conclusions

In all the above examples of implementation projects comprising modifications of ERP-class information system, it was first decomposition and deconstruction to be used. Such an approach is correct in case of non-homogenous character of the works in the project. The best example are the projects including: modification of existing functions, adding new functions to the existing ones, the procedures of data transfer. In case of decomposition it is possible to compensate the underestimations of some parts and overestimations in others, what was particularly visible in U02142. Support for this thesis can be found in Lum Karen et al. [23] among others, therefore, the authors focused on other methods instead.

Considering economic criteria, particularly the first degree margin at the level of 30%, one may conclude there are satisfactory results are generated by those methods, whose estimation error is higher than 15% (with 15% of margin in the underestimation). The range of errors that were made using the estimation methods and a set of methods in Table 10.

Type of work	Method 2	Estimation [h]	Implementation [h]	Estimation error	Standard deviation of errors
W_1 do W_8	Summing, computing, evaluating	263	204	-23%	34%
W_9 do W_21	Expert valuation	140	136	-3%	79%
W_22 do W_30	Expert valuation	53	79	49%	74%
	Total	456	419	- 8%	

Tab. 9. Comparison of real and estimated costs in project U02142

Method of estimation	Distribution of errors	Standard deviation of errors
Individual expert evaluation	380%	from 31% to 79%
Wideband Delphi (group expert evaluation)	60%	from 18% to 64%
By analogy	115%	from 23% to 143%
Substitution bsed	23%	21%
Summing, computing, evaluating	49%	74%

Tab. 10. Comparison of estimation method errors

One should notice that the method of individual expert evaluation can generate large distribution of errors in case of scattered evaluations. It is only the reconstruction that enables neutralisation of errors, what makes complete estimation more precise (see project U02142).

Detailed evaluation made by experts in Wideband Delphi groups generated the results burdened with a significant error, even though more precise estimations had been anticipated than for individual expert evaluations.

The above list shows that the most risky list is the estimation method based on analogy. In project U03333 significant mistake in this method was caused by adopting analogical case from another project context.

Evaluation method based on substitution seems more exact, however, its errors at the level of 20% are above the adopted limit.

Summing, computing, evaluating was used in one project only. The distribution of errors and standard deviation seem unsatisfactory, in comparison to other methods.

In all cases the suppliers provided the same reason for exceeding the estimated value of costs: disturbing system stability after integration in a standard information system.

Summarising, it can be concluded that for any selection of information technology project evaluation, none of these methods or their combinations generate a satisfactory result. Another step to develop a solution for IT project managers, who attempt to estimate the costs of IT system modifications with predictable certainty is to select such a class of IT products, for which specific methods generate satisfactory results.

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Key words:
ERP systems, software modifications, cost estimation.

Abstract:
During the sales process of ERP systems, it appears that a set of standard functionality must be extended or modified according to customer requirements. Suppliers are facing of the problem of determining the cost of additional work. The paper presents a non-algorithmic method of software cost estimates. It described three cases of implementation ERP projects using these methods to estimate the cost of the modification. On this basis, analyzed the differences between the estimated and actual values. This article tries to answer the question whether the selecting method of evaluation, suppliers can expect to specified accuracy of estimated values.

WYBRANE METODY WYCENY MODYFIKACJI SYSTEMÓW ERP

Słowa kluczowe:
systemy ERP, modyfikacje oprogramowania, wycena kosztów oprogramowania.

Streszczenie:
W trakcie procesów sprzedażowych systemów ERP okazuje się, że zbiór standardowej funkcjonalności musi być rozszerzony lub zmieniony (zmodyfikowany) zgodnie z wymaganiami klienta. Dostawcy stoją zatem przed problemem określenia kosztów dodatkowych prac. W artykule zaprezentowano niealgorytmiczne metody wyceny kosztów oprogramowania. Opisano trzy przypadki projektów wdrożeniowych wykorzystujących te metody do estymacji kosztów modyfikacji. Na tej podstawie przeanalizowano różnice między szacowanymi i rzeczywistymi wartościami. W artykule można znaleźć odpowiedź na pytanie, czy wybierając metodę oceny można oczekiwać zadanej dokładności estymacji.

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