Prediction Model for Characteristics of Implementation of Information Systems in Small and Medium Enterprises

I. Nazor, K. Fertalj, and D. Kalpic

Abstract—**The process of choosing an Enterprise Resource Planning (ERP) solution for a Small and Medium Enterprise (SME) is often uncertain and not well defined. In the process of development of a comprehensive methodology for selection of ERP for SME, a prediction model is designed, with the aim of assisting buyers of ERP solutions by predicting certain characteristics of the implementation process.**

All necessary elements for the prediction process have been designed: parameter set, prediction model, online questionnaires for experts and for the ERP buyer - client, and a software tool. The tool collects, verifies and analyzes collected data and predicts relevant properties of the new ERP implementation project, such as cost, duration, intensity of Business Process Reengineering (BPR) or intensity of users training.

The tool interacts with the client in the form of an interview. After each answered question, estimates for all properties of the new project are recalculated, with an increased precision, based on additional data. In order to make the interview process flexible, any question in the interview can be skipped, or the interview aborted at any point and the tool will calculate the best possible prediction for the new project properties based on the available information.

Index Terms—**ERP, implementation, knowledge base, project features prediction, SME.**

I. Introduction

In today's world, the competition is generally fierce, especially in the area of Enterprise Resource Planning systems (ERP). There are literally thousands of ERP systems in the world, and even more companies that implement them. While a potential buyer of an ERP will obviously narrow the search to the locally available ERP systems and the ones compatible with local business practices and legal requirements, options for a typical Small and Medium Enterprise (SME) are usually still numerous.

A classical approach to ERP system selection described in literature, typically consists of these steps: 1) *Forming a team of experts*, usually consisting of both internal and external experts, in charge of defining the goals and strategy of ERP implementation, project feasibility [11] 2) *Assessment of the current situation*, which includes documenting business processes and requirements for the new system, 3) *Defining the set of criteria for evaluation of the new ERP solution* [1], [2], [4], [6], [8], [11], [15], [18], [19], 4) *Collecting offers from the vendors*, 5) *Evaluating offers according to the given criteria,* [12]-[13], [17] and 6) *Making the final selection*.

Manuscript received September 6, 2012; revised October 31. 2012.

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There are ample references in literature on hierarchies of parameters describing properties of companies buying ERP [11]. Characteristics described comprise the level of involvement of the client's key users [15], IT literacy and flexibility of employees [16], level of involvement of management and its efficiency in dealing with current problems [10], [12], client's capacity of managing complex projects [7], [9], [25], organizational efficiency and the level of BPR performed during implementation [1]-[3], client's negotiating strength, and important characteristics of the vendor's company [15].

SME can be defined as a company having between 10 and 250 employees, or the annual income of less than 40M€ [3]. SMEs by default have limited resources, both in terms of staff and finances [5], there is usually a lack of knowledge needed to select and manage an ERP implementation project.

When choosing a new ERP system, a typical decision maker in SME, usually the owner or chief executive officer is constrained with time, money, IT knowledge and internal organizational support. As the result, purchase decision is often taken based on less relevant factors, which are emphasized during ERP vendors' fancy presentations. As a further consequence, the project of implementation of the new ERP system is often late, exceeds budget and fails to meet the customer's expectations. According to [14], 40% of software implementations in SMEs are never completed and 20% are considered failures. Results of an online survey about satisfaction of small companies with their ERP system show a relatively high level of dissatisfaction.

Compared to ERP implementation projects in large enterprises, projects in SME are much simpler, depend on a smaller number of parameters, and are managed by less people. Furthermore, it is assumed that the manager of such project has a good overview of all details of the project, and his knowledge is relatively easy to collect in a formalized and comparable way.

The aim of this research is to assemble a pool of knowledge about past ERP projects and to formulate an algorithm that guides the potential buyer through a series of questions, providing an insight into certain aspects of their ERP project, which becomes more precise with each question answered.

Tools for selection of ERP solutions are available as Internet services, but they are not adapted to a typical decision maker in a SME, who usually lacks insight into the problem and the knowledge to impartially answer the series of complex questions that are asked. Furthermore, solutions that have been analyzed, mostly focus on comparing features of different ERP systems based on specified customer requirements, without providing a deeper insight into what the entire ERP implementation process would look like.

DOI: 10.7763/IJIMT.2012.V3.330

II. Prediction Model

The first research hypothesis is that a typical decision maker in a SME does not have enough knowledge and time to make a precise specification of his or her needs, specify the relevant criteria for an ERP solution to meet, and make objective evaluations of the proposed alternatives.

The second hypothesis is that vast knowledge is existing about implementation of ERP systems in SMEs, which can be easily collected because a large number of such implementations have been already completed.

The proposed method is based on the described hypotheses, and consists of three main steps:

1) Definition of hierarchies of parameters to store the collected knowledge, with corresponding metrics and domains of values. Determining groups of parameters that hold specific views, contexts, relations between contexts, as well as the appropriate set of rules for interpretation of measurements across different domains.
2) Collection of expert knowledge, via online questionnaires. The main source of information are consultants who have managed ERP projects in SMEs in the past. This knowledge is stored in the parameters of the context "Past ERP Projects". Additionally, generic knowledge about mutual influence of different properties of ERP implementation projects (software, client, implementer's staff), viewed in the context of "Generic ERP knowledge" can be collected and used to determine weight factors in the simulation phase. After the knowledge is gathered, statistical processing (Fig.1), is run to calculate the elements for regression analysis. Prediction is run by calculating individual values of parameters in the "New Project Properties" context, which are linearly combined particular weights. Four methods of determining parameter weights were investigated: assigning equal weights to all parameters, using values obtained from regression analysis, interpreting the results of the generic knowledge questionnaire from the previous step, and using the number of measurements available for each parameter as its weight coefficient.

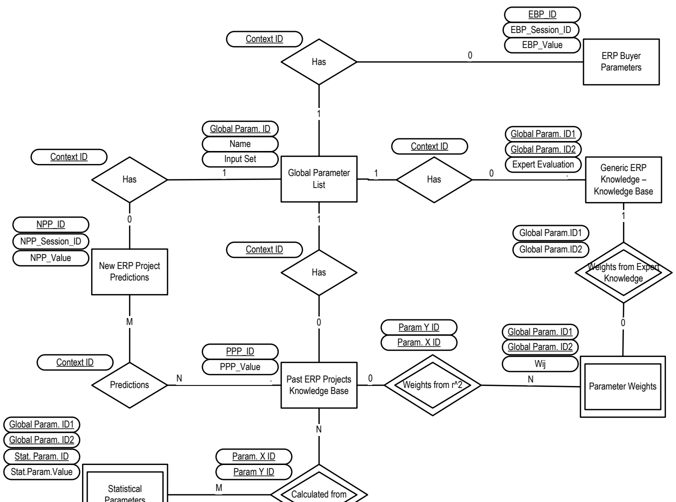

Fig. 1. E-R diagram of the conceptual data model used for prediction

3) Interview session with the potential ERP buyer, where the interviewee is asked to grade certain characteristic of his company. The questions are aimed at determining the level of potential buyer's motivation, financial strength, and organizational maturity. The results are compared against the knowledge stored in the database using elements of regression analysis. The process of predicting elements of a future ERP project is run after every answer received from the client, with increased precision as the interview progresses.

III. Parameter Set

Parameter describes a property of an ERP functionality, a characteristic of client's company or property of an ERP implementation project. Attributes of a parameter are: name, global identifier, one or more context-related identifiers, input set and the mapping function.

Context is a specific view on a parameter, depending on the purpose for which it is used. There are four contexts: "Past Project Properties", containing formalized expert knowledge, "Dependencies", used for collecting generic expert knowledge on ERP implementations, and "Buyer's Company Properties", containing characteristics of the client's company and their plans regarding the new ERP system, collected during the prediction session via an interview, and the context "New Project Properties" contains the final result of the simulation process, i.e. the predictions of significant properties of the new ERP implementation project. Different contexts are shown as entities in the diagram in Fig.1.

In the proposed model there are 91 parameters, observed in four different contexts. Prior to processing, all measurements are mapped to a real subset [0,1], by means of the mapping function

$$B: \quad \to C, \quad \in [0,1] \tag{1}$$

where A is a parameter's input set, and C is the real interval [0, 1], scaled for calculations.

In case where the input set A is a linguistic variable with a finite set of n linguistic values, the interval [0,1] is divided into n-1 equal sections, and the input values are mapped to the appropriate value in the [0,1] set, with the first element mapped to 0, and the n^{th} to 1.

As an example, the linguistic variable with elements: "very low", "low", "medium", "high", and "very high" would be mapped to values 0, 0.25, 0.5, 0.75, and 1, respectively.

When mapping of linguistic variables, one must differentiate between two kinds, where A denotes an ascending series, $a_i < a_{i+1}, \forall a_i \in A$ and when its elements are not strictly arranged in ascending order.

The first case is Likert scale variables ("very low", "low", "medium", "high", and "very high"), where "very low" obviously means less then "low". In this case, the mapping rules for A are the same as for a continuous set of numerical values.

The other possibility is that a variable with a number of linguistic terms is used for classification, where one cannot compare two values in terms of magnitude. An example would be classification according to business operations, with possible values: "trade", "manufacturing", "other". In this case, a different approach should be considered, possibly using binary variables. Classification variables are planned for use in the extended version of the described methodology, and at that time, the correct approach would be devised.

In the case of standard linear mapping, if A is an ascending series or a continuous set of numerical values, and B is a linear mapping function B within the two bounds, their functional dependency is:

$$B(A) = \begin{cases} \dfrac{A - Lbound}{Hbound - Lbound} A; Lbound \le A \le Hbound \\ 0; A < Lbound \\ 1; A > Hbound \end{cases} \quad (2)$$

Hbound and *Lbound* are upper and lower values for which the function is linear.

It was often observed that the significance of values could not be well explained only by a linear function, so an additional mapping option was introduced. An ascending series of steps *S* is introduced between *Lbound* and *Hbound* with $B(S_i)$ distributing mappings evenly throughout the range C.

$$\forall S_i \in R, S_{i+1} > S_i; i = 1,2,..,k; k \in N \quad (3)$$

$$B(S_i) = \frac{i}{n+1}; Lbound < S_i < Hbound \quad (4)$$

Therefore, the first option of mapping function (2) is merely a special case of (3), with *i=0.*

In an example shown on Fig. 2, the parameter P39, "Average age of employees", has numeric set A, Lbound 30, and *Hbound* 60. Therefore, any age between 30 and 60 is mapped linearly. On the other hand, the parameter P20, "Increase / Shortening of planned implementation time", in addition to *Lbound* = 0 and *Hbound* = 180, has steps 30, 60, 150.

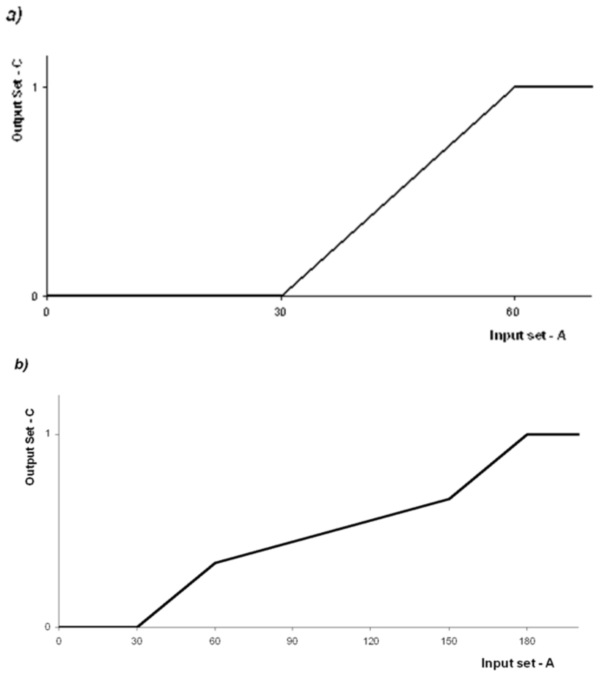

Fig. 2. Linear mapping function without and with steps

In practice, mapping with steps would mean that an increase in variance of implementation time between 0 and 30% has a stronger impact than the same increase, but after an already existing delay of 60%.

For the purpose of interpretation of the results, the results of calculations are mapped back from the set [0, 1] into the original input set.

Mapping from real set [0,1] back into the linguistic set is done by finding the closest step value, and mapping it into the corresponding linguistic value. For example, the value of 0.24 is mapped to "low" because its closest step value in the [0,1] set is 0.25.

As an example, the parameter "Average age of employees" has global identifier 39. It is tagged "E2" in the "New Project Properties" context, and "K6" in the “Buyer’s Company Properties” context. Its set of input values is numeric, and the value denotes a person’s age. Its mapping function is linear.

Parameter P15, "Level of BPR during implementation" has linguistic input set with possible values: “none”, “low”, “medium”, “high”, “very high”. If the result obtained after calculation is, 0.95, value 1 would be used as the input value for mapping to the linguistic set, because |0.95 - 1| < |0.95-0.75|. The linguistic value equivalent of 1 is “very high”.

If one views value mapping in terms of Fuzzy set theory, in this case triangular Fuzzy membership function is used. In a different approach, any other type of Fuzzy membership function could be used. At this time, however, the suitability of other membership functions has not been investigated, which is left for further research.

IV. Knowledge Acquisition

The idea is to formalize the expert knowledge about the implementation of ERP systems. There are two sources of expert knowledge, interviews with leaders of specific ERP projects in SME and interviews collecting generic knowledge about dependencies between ERP implementation critical success factors. In both cases, the knowledge is gathered via online questionnaires, which store responses into an online spreadsheet document. The raw data is later pasted into an Excel sheet with added functionality for data parsing, data interpretation, and running simulations.

The first questionnaire collects data in the context “Past ERP Projects”, that contains 59 parameters. During each session, the expert answers questions about a single ERP implementation project. The questionnaire is divided into 5 sections: “General information”, “Quotation phase”, “Implementation process”, “End of implementation”, and “Client's staff and organization”. Sections describe different phases of an implementation project, (before, during, and after the implementation) and certain organizational and personnel characteristics of the client's company. Some questions ask for descriptive answers, which are not numerically processed later, while most of them require either a number or a linguistic variable as an answer, and are interpreted in a formalized way.

Questions in the “Quotation phase” assess how well the elements of the project were estimated in the quotation, including the project's duration, hours of staff training, overall costs, and project's revenue.

Assumption based on the researcher's experience from managing ERP implementation projects is that, in the initial phase of implementation, an intense direct contact is essential between implementer's staff and key users from all interested units in the client's organization. Reducing this contact or replacing it with alternatives such as teleconferencing, remote access, e-mail, phone calls, chat etc., may result in problems. The key players may not get acquainted personally with the implementer's staff, the need to communicate well between each other and between departments on all levels may not be clarified enough, making a poor foundation for resolving issues that may arise later in the implementation process. Questions in the "Implementation phase" deal with such characteristics as physical distance between people and departments in the organization and the distance the implementer's staff needs to travel to reach the client's company.

The questions in the "End of implementation" section determine the accuracy of estimates of project's scope and size (duration, number of licenses, price), outside problems that may have had an impact on the project flow (financial issues, tracking of work performed, issues when completing the project), as well as the efficiency of using remote access for dealing with client's staff. Surprisingly, the parameters that indirectly describe internal efficiency of the implementer have received relatively high negative grades.

The last section, "Characteristics of clients organization and staff", classifies client's business operations, evaluates certain organizational characteristics (process maturity with questions using a very simplified Capability Maturity Model - CMM questionnaire, efficiency of organizational structure, level of interdepartmental communication), efficiency of management's resolving issues during implementation, and some characteristics of employees (age, IT literacy, experience, flexibility, speed to adopt new skills).

The second questionnaire, "General ERP implementation knowledge", deals with the parameters in the "Dependencies" context. It is aimed at collecting generic expert knowledge, not related to a single implementation. Dependencies between 19 parameters are evaluated, by means of an ascending series of 10 values, ranging from 0 ("insignificant") to 9 ("extremely significant"). Questions are aimed at finding out how much a certain characteristic of a potential ERP buyer influences the outcome of the entire implementation. One can argue that that this approach is imprecise, and that a more detailed questionnaire should be used, grading influence of the set of characteristics of a potential customer to the full set of required characteristics of an implementation, in all possible combinations, and not just one "outcome of implementation". An improvement of this model, probably using a full Analytical Hierarchy Process (AHP) evaluation is considered in future work.

V. Simulation

Simulation is performed by means of an interview, where the client answers questions in a questionnaire, formed from the parameters in the context "Buyer's Company Properties". Each answer provides an input value for the prediction model, which then values for the variables in the context "New Project Properties". With each new answer, the simulation should give a more precise estimate of all of the expected properties of the new ERP project.

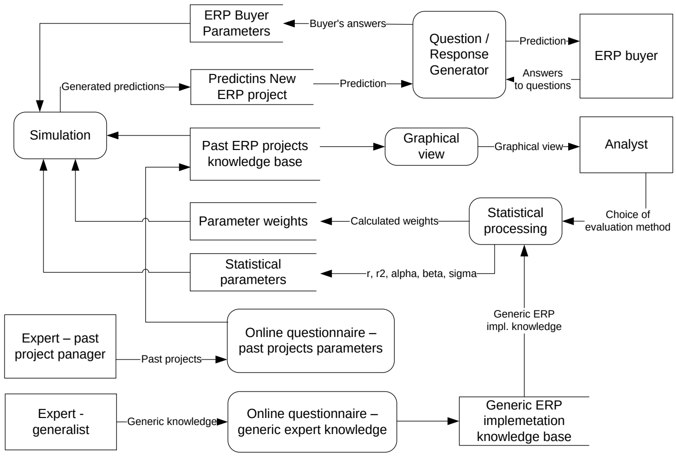

Fig. 3. Data – flow diagram of the prediction model

Predictions are calculated using parameters obtained through regression analysis, which attempts to find a function that best describes the dependence between two statistical variables, based on their measured values. Input values for the regression analysis are taken from the Past Project Parameters knowledge base.

The first step is to extract the measurements for the parameters analyzed. A graphical display of this is shown by dots on X-Y graph on Fig. 4.

The next step is to determine the nature of the function that will be used to approximate the measured values. Usual options are a linear function or a higher-level polynomial. The requirement on the function is that it should pass at a smallest possible squared distance from all the points on the graph (Fig. 4).

Once obtained its parameters, the regression function can be used to predict the value of variable Y when the value of X is known.

Fig. 4 shows an example of the regression function for the parameters P41 "Level of resistance of employees to change" from the context "Buyer's Company Properties", on X axis, and P20 "Extension / shortening of planned implementation time", from context "New Project Properties", as a dependent variable, on Y axis.

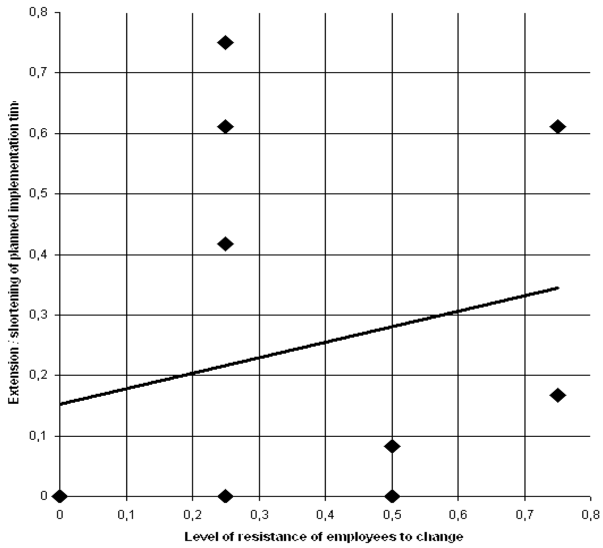

Fig. 4. Linear regression function example

Linear regression function, $F(x) = \alpha + \beta x$ was used in this case, with the formula, with β as the line slope and α as intercept. In this example $\beta = 0.2577$ and $\alpha = 0.1521$.

The input set of P41 is a linguistic variable with five possible values: “very low”, “low”, “medium”, “high”, and “very high”. P20 has a numeric input set, and a stepped linear mapping function with $Lbound = 30$, $Hbound = 180$, $S_1 = 60$ and $S_2 = 150$. If the client estimates the “Level of Resistance of Employees” in their company to “medium”, it is mapped to value 0.5.

By using $x = 0.5, F(x) = 0.2577x + 0.1521$, the projected value is 0.28095, which, when mapped into the input set of the parameter “Extension / shortening of implementation time” equals 33.71%. Hence, for a medium level of employees’ resistance to change, the project is expected to be prolonged by 33.71%.

Coefficient of correlation, *r*, determines how precisely the function of regression describes the relationship between two variables. Value of *r* varies between -1 and 1, and closer its absolute value is to 1, the better it approximates measured values. In an ideal case of $r = 1$, all the measured values (dots on X-Y graph) would be laid exactly on the regression function, the two variables would have a functional dependence, and one could make predictions with high certainty.

In the example shown on Fig. 4, the coefficient of correlation is relatively low, 0.704, since, as can be seen on the graph, the measurements are relatively far from the line of regression.

Using the described method, and based on known value of one parameter, (i.e. one answer from the client) one can make predictions for all the parameters, which are statistically related to the known parameter.

In this example, the information from the buyer that the value of parameter P41 is “medium” is enough to make predictions on most of parameters in the “New Project Properties” context. Naturally, one must consider the fact that the accuracy of prediction of each parameter depends on the correlation coefficient between two variables in question.

The simulation process is performed on two parameter sets (contexts): “New Project Properties” (*P*), and “Buyer’s Company Properties” (*B*). After k^{th} iteration of question and answer, the value of j^{th} parameter in the set P is:

$$p_j = \frac{\sum_{j=1}^{n}\sum_{i=1}^{k} w_{ij}(\alpha_{ij} + \beta_{ij} b_i)}{\sum_{i=1}^{k} w_{ij}} \tag{5}$$

$p_j \in P, b_i \in B, n \in N, m \in N$

where *m* and *n* are counts of elements in sets *P* and *B*. Answer to each question should bear a certain weight in the total value of the estimated variable. w_{ij} is the weight of i^{th} projection in the resulting value of j^{th} element of *P*. In order to normalize the total value to the range [0,1], it is divided with the sum of weights for p_j over *i*.

Since all values are normalized before calculation, the resulting y_j is also in the interval [0, 1]. After calculation, the result is mapped into the input set using each parameter's mapping function.

Various methods of determining weight factor w_{ij} are considered:

- Assigning equal weights to all answers, $w_{ij} = 1; \forall i \le m, j \le n$
- Using coefficient of determination r^2 between x and y as weight factor, adjusted for the sum of weights over all variables x,

$$r_{xy}^{\ 2} = \left(\frac{\sum_{k=1}^{l} (x_k - \bar{x})^2 (y_k - \bar{y})^2}{\sqrt{(x_k - \bar{x})^2 (y_k - \bar{y})^2}} \right)^2 ; l \in N \tag{6}$$

- Determining weights between parameters by gathering expert knowledge, as described in the section "Knowledge Acquisition".
- Taking into consideration the number of measurements used for calculating statistical values. Since the questionnaire is flexible, allowing respondents not to provide an answer, it often occurs that a relation between two variables is calculated on the basis of a small number of measurements *n*, which intuitively leads to a less reliable measure. This could be taken into account when calculating w_{ij}, by multiplying it with ratio n/n_{max}. During testing of the model’s precision, this led to a small increase in precision.

VI. Conclusions

As it is very often the case while collecting large amount of information from humans, availability of respondents is the main bottleneck. When creating the data collection methodology and the parameter set, conflicting demands need to be addressed: The client needs precise answers, simply and quickly, it is difficult to predict their areas of expertise, and which of the information provided is the most relevant for the knowledge database.

The knowledge database needs to address many details on many topics, in order to provide relevant connections between the buyer’s answers and the knowledge stored. Filling an extremely detailed knowledge base would be a big challenge, due to unavailability of experts, and the time they would be willing to spend answering questions. Furthermore, many questions are not answered for various reasons, be it sensitivity of information asked, or lack of time or knowledge.

The proposed parameter set is an attempt to minimize all of the problems mentioned. During research, many parameter sets from the available literature were considered, and those that would be most understandable to an unskilled end user, while being easy and straightforward to estimate for experts, were chosen.

As the collection of data from experts is still in progress, the model’s precision is increasing with more data collected. At this stage, the aim is to validate the model, select the right simulation methodology, and eventually make corrections to the parameter set, while retaining the mentioned properties of understandability and ease of answering.

VII. Future Work

The precision of estimates of the proposed methodology remains to be tested with more expert knowledge. At this stage, the aim is to validate the model, select the right simulation methodology, and eventually make corrections to the parameter.

It is estimated that at least 100 questionnaires about specific ERP projects, and at least 10 generic-knowledge questionnaires need to be collected in order to stabilize the regression parameters. Then it will be possible to make a better judgment as to which method of determining weight factors, and which regression function give the best results.

When the knowledge base increases, it will make sense to classify the projects into groups according to different criteria, such as their industrial activity, number of employees or geographical location. The buyer's company will then be compared against the closest-matching group in the knowledge base, and additional parameters, such as "ERP system implemented in the closest-matching company". Having a detailed classification on a small number of responses would decrease the number of available measurements below a statistically relevant number.

Another way of increasing the relevance of the knowledge stored in the knowledge base could be to classify expert's answers according to the overall success of the project that they were managing. Metrics for the successfulness of a project would be devised, and the grade obtained could act as weight factor for all parameter's grades in a particular evaluation. Parameters like project schedule delay, budget cost overrun, level of BPR during implementation or improvement of process maturity during implementation can be considered as a measure of ERP project's success.

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