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Criteria for ERP selection using an AHP approach

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Abstract — Information systems are a foundation key element of modern organizations. Quite often, chief executive officers and managers have to decide about the acquisition of new software solution based in an appropriate set of criteria. Analytic Hierarchy Process (AHP) is one technique used to support that kind of decisions. This paper proposes the application of AHP method to the selection of ERP (Enterprise Resource Planning) systems, identifying the set of criteria to be used. A set of criteria was retrieved from the scientific literature and validated through a survey-based approach.

Software packages selection; AHP method; ERP selection criteria

I. INTRODUCTION

In many organizations, ERP (Enterprise Resource Planning) systems are the information engine that supports the running of business processes.

ERP systems emerged from the manufacturing resource planning systems, which integrate all the information about the enterprise manufacturing processes, incorporating new functionalities to support the complete enterprise processes. An ERP system comprises several packages, enabling an enterprise to integrate the data through its entire organization [1].

Therefore, the selection of ERP software is a critical decision for an organization. Because it is generic software, able to touches every single process of the organization, it imposes its own logic and culture. It enforces generic processes over customized ones.

To support complex decisions, organizations often use decision-support tools in order to identify the more advantageous scenarios [2], [3]. In the software packages selection context, organizations use different approaches as referred in [4–6].

The research study, described in this paper, is about the use of the Analytic Hierarchy Process (AHP) method in the selection of ERP software packages. The goal of the research study is to develop a framework tool for the selection of the more appropriated ERP software package from several alternatives of ERP suppliers/solutions in the context of Portuguese organizations. This paper presents the first phase of the study, which consists of the elicitation of the set of criteria to be used in the selection process.

In the next section, we present a literature review about the ERP systems and the use of Multi-Criteria Decision Making (MCDM) methods. Third section introduces the method used in the study and following section describes the tasks developed in the scope of this paper; fifth section discusses the results and last section presents some conclusions and the next steps of this study.

II. USE OF AHP IN ERP SELECTION

In the scientific literature there are many studies about the application of MCDM methods to the selection of software packages. Jadhav and Sonar [7] performed a study about evaluating and selecting software packages that includes a systematic review of methodologies for selecting software packages and software evaluation techniques. They concluded the application of AHP to the evaluation of software package has been successfully applied in many research studies.

A. ERP systems

ERP systems promise the seamless integration of all the information flowing through a organization, including, financial and accounting information, human resource information, supply chain information and customer information. The ERP collects data from and feeds data through modular applications supporting, virtually, all of a company's business activities, across the different business...
units. When new information is entered in one place, related information is automatically updated [1].

The advantages for the organization, in terms of management and user productivity, are vast. By implementing ERP systems the organizations aim to achieve, using Information Technology (IT), the capability to plan and combine enterprise-wide resources, integrating the applications and processes of the various functions [8].

However, when an organization implements an ERP system, the business processes and operating principles keep locked into the software. ERP pushes a company toward full integration even when it is desirable a certain degree of business-unit segregation. There are many cases where customized processes are a source of competitive advantage compared with more generic processes imposed by ERP systems [1].

If an organization fails to reconcile the technological imperatives of ERP system with its business needs, the logic of the system may conflict with the logic of business systems[1]. Installing an ERP system is much more than having another information technology tool; it is a decision on how to shape the organizational business [8]. Thus, the selection of an ERP software package is a critical decision for an organization.

B. MCDM methods

MCDM methods help decision makers choose the best alternatives between a group of considered alternatives, by ranking the alternatives in decreasing order of performance or identifying the ones that are good or appropriated. There are different kinds of MCDM methods, such as AHP (Analytic Hierarchy Process); ANP (Analytic Network Process); WSM (Weighted Sum Model); WPM (Weighted Product Model); and fuzzy MCDM approach.

AHP method was introduced by Thomas Saaty [9] and it has been used extensively in multicriteria decision-making, having been studied, improved and refined since then. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements; the elements relate to global targets in the evaluation of alternatives.

The AHP method has been used as a MCDM tool that enables a systematic comparison of alternatives. AHP method is applicable to virtually all areas of decision-making [10]. It has been applied in several areas such as economic planning, energy policy, project selection, resource allocation and budget allocation [11]. AHP has been successfully used to support the selection of software solutions, such as generic software packages [7], software architectures [12], simulation software packages [13], knowledge management tools [14], and ERP systems [6], [15].

A significant limitation of AHP is the assumption of independency among various criteria of decision-making. Contrary to AHP, ANP provides a more generalized model in decision-making without making assumptions about the independency of the higher-level elements from lower-level elements and also of the elements within a level. Despite all these merits, the applications of ANP are not very common in a decision-making problem [16].

The research study adopted AHP because it was positively used as a decision support method for software packages and, in particular, ERP systems. The core principle of AHP is to break down decision problem into a hierarchy of sub-problems, thereby structuring the decision, what make it suitable for handle complex decisions [9], [17]. This method can be used to rank physical and social alternatives, what is a distinctive characteristic of AHP [18].

WSM and WPM are ease to use but are seldom used as a MCDM method because weights to the attribute are assigned arbitrary and it is very difficult to assign weight when the number of criteria is high. Fuzzy based approach improves decision-making procedure by accommodating the vagueness and ambiguity occurred during human decision-making. However it is difficult to compute fuzzy appropriateness values and ranking values for all alternatives [7].

III. METHOD

Decision-making can be defined as a six steps process [19]: (1) model de problem into key elements and its relationships; (2) get the assessment of these elements and (3) represent them quantitatively; (4) use the results to calculate the priorities; (5) synthetise to get an overall outcome; and (6) analyse sensitivity to changes in judgment.

This research study aims to help the accomplishment of the first step by developing a framework to help to map the problem in a model that represents the problem’s key elements and their relationships in a hierarchy, for the specific case of ERP Systems. That’s the goal of the study described in this papers.

The second and third steps correspond to the quantitative assessment of these elements by the participants in the decision process that capture their knowledge, feelings, or emotions. These steps can be accomplished using a questionnaire based in the model that will emerge from step one.

In the context of this research study will be developed a software tool to support steps four and five: calculate the priorities of the elements of the hierarchy and synthesize these results to determine an overall outcome. Step six consists of the sensitivity analysis to changes in the assessment input and is out the scope of the research study.

One of the most creative parts of decision-making is modelling the problem, which has a significant effect on the outcome. In the AHP, a problem is structured as a hierarchy [19]. To assess the several ERP alternatives we need to identify a set of criteria that will be used in the evaluation process. This study used the following approach:

A. Identification of the initial set of criteria by performing a literature review about the most common criteria used for ERP selection;

B. Elicitation of the samples, i.e., the persons that assess the criteria identified in step A, and validation of the questionnaire;
C. First survey — used two samples, a restricted sample and a general sample, to assess the criteria obtained from the literature review;

D. Second survey — used the restricted sample to assess new criteria, by including it in a refined questionnaire, and to confirm or change to evaluation of step C.

The above method is based in some principles of the Delphi method. Delphi method works especially well when the goal is to develop predictions about a given topic or to improve our understanding about the problems, opportunities, and solutions. It has been used successfully in Information Systems (IS) research [20].

A research according the classic Delphi method must encompass four main characteristics [21]: anonymity, iteration, controlled feedback, and the statistical aggregation of group response. The group of participants shall expose their understandings freely, without any pressure or constraint. Each iteration, the participants can refine and reconsider their view in light of the progress of the group's work. Controlled feedback shall be provided to inform participants about of the opinions of their anonymous colleagues. The statistical association of the group's response shall allow a quantitative analysis and data interpretation [21].

The literature review used in the first step of the method to elicit the initial set of criteria, has a twofold goal: (1) limits the number of iterations and allows a fast converge of results; and (2) provides the background knowledge to the researchers.

Each sample elicited in step B has distinct purposes. The restricted sample will consist of a small group of persons that have experience in the implementation of ERP and participated in ERP selection processes. The general sample will provide a wide perspective about the selected criteria.

Based in the Delphi principles, the restricted sample will assess the criteria initial set of criteria, in step C, and will have the opportunity to reassess their vision in step E. The restricted sample participants are confronted with the overall results of the step C survey. In the end of this process, the resulting set of criteria and respective assessment are structured in the hierarchy with specific weights assigned to each criteria, such as the AHP method demands.

IV. TASKS DEVELOPED

This section presents the tasks developed in this research study according to the four steps of the approach described in the previous section.

A. Literature review

The literature review was performed over several scientific reference portals using a combination of the keywords “ERP”, “AHP”, “decision”, “software packages”, and “evaluation”.

Table 1 shows a list of the selected criteria and the papers that support each one. The references included in the table are restricted to a subset of eleven papers. Based in the literature review, the criteria were organized into two main subgroups, ERP vendor and ERP software package. This structure is presented in many papers and results by the fact that the selected criteria either respect to the ERP vendor or to the ERP software package.

<table>
<thead>
<tr>
<th>Criteria level 1</th>
<th>Criteria level 2</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical team capability</td>
<td>[5], [15], [22–24]</td>
<td></td>
</tr>
<tr>
<td>Technical support quality</td>
<td>[15], [22], [25], [26]</td>
<td></td>
</tr>
<tr>
<td>Consultancy services</td>
<td>[15], [22], [23]</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>[5], [15], [22], [23], [25], [27]</td>
<td></td>
</tr>
<tr>
<td>Implementation ability</td>
<td>[15], [23]</td>
<td></td>
</tr>
<tr>
<td>Guarantees</td>
<td>[15], [24], [25]</td>
<td></td>
</tr>
<tr>
<td>Market share / scale of the vendor</td>
<td>[5], [15], [26], [28]</td>
<td></td>
</tr>
<tr>
<td>Financial condition</td>
<td>[5], [15], [28], [29]</td>
<td></td>
</tr>
<tr>
<td>Portfolio</td>
<td>[5], [23], [25], [26]</td>
<td></td>
</tr>
<tr>
<td>Payment and financial terms</td>
<td>[25], [27]</td>
<td></td>
</tr>
<tr>
<td>Operating system compatibility</td>
<td>[5], [25], [27]</td>
<td></td>
</tr>
<tr>
<td>Hardware requirements</td>
<td>[5], [25], [29]</td>
<td></td>
</tr>
<tr>
<td>Database engine compatibility</td>
<td>[5], [22], [25], [27]</td>
<td></td>
</tr>
<tr>
<td>Integration support</td>
<td>[5], [15], [22], [23], [26], [27], [30]</td>
<td></td>
</tr>
<tr>
<td>User friendliness</td>
<td>[5], [22], [27], [28]</td>
<td></td>
</tr>
<tr>
<td>Documentation quality</td>
<td>[25], [27], [30]</td>
<td></td>
</tr>
<tr>
<td>Online help and tutorials</td>
<td>[5], [22], [25]</td>
<td></td>
</tr>
<tr>
<td>Documentation in native language (Portuguese)</td>
<td>[25]</td>
<td></td>
</tr>
<tr>
<td>Software licencing cost</td>
<td>[5], [23–25]</td>
<td></td>
</tr>
<tr>
<td>Hardware/infrastructure cost</td>
<td>[5], [23], [25], [29]</td>
<td></td>
</tr>
<tr>
<td>Integration/middleware cost</td>
<td>[15], [25], [30]</td>
<td></td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>[5], [15], [23], [24]</td>
<td></td>
</tr>
<tr>
<td>Software acquisition cost</td>
<td>[5], [24], [29]</td>
<td></td>
</tr>
<tr>
<td>Consultancy cost</td>
<td>[15], [23], [28]</td>
<td></td>
</tr>
<tr>
<td>Function–fitness/ module completion</td>
<td>[22], [24], [30]</td>
<td></td>
</tr>
<tr>
<td>Scalability and upgrade ability</td>
<td>[15], [23], [26], [27]</td>
<td></td>
</tr>
<tr>
<td>Customization</td>
<td>[15], [24], [26], [27], [30]</td>
<td></td>
</tr>
<tr>
<td>Source code availability</td>
<td>[24], [25], [30]</td>
<td></td>
</tr>
<tr>
<td>Security</td>
<td>[5], [15], [27]</td>
<td></td>
</tr>
<tr>
<td>Stability and recover capability</td>
<td>[15], [23], [25]</td>
<td></td>
</tr>
</tbody>
</table>

B. Elicitation of samples and validation of the questionnaire

The preparation of the questionnaire and the samples selection was performed in parallel. The first step in the questionnaire preparation was to formulate each criterion as a question. The questionnaire included the criteria presented in table 1 with a modification: the criteria “online help and
The questionnaire was structured as simply and direct as possible. Each criterion was complemented with a little help text. To assess the relevance of each criterion, the questions were presented according to the five-point Likert item.

As mentioned previously, the study used to distinct samples: (1) the restricted sample, consisting of ERP specialists and actors in the process of decision and contains of 60 elements; (2) the general sample is constituted by 1511 elements and integrates IT professionals from information systems consultancy enterprises, ERP systems customers, and IT suppliers.

The online surveys were accomplished using the LimeSurvey\(^1\) open-source platform. It is free of charge, has no usage restrictions, supports direct export tools for data processing and allows customization.

The questionnaire validation is required to achieve valid results. The test of the questionnaire was done by performing a survey to a subsample of 80 persons of the general sample. 22 persons answered the survey and it resulted 21 valid answers.

The internal consistency of the questionnaire items was performed through the method of Cronbach's Alpha, which obtained a value of 0.862, confirming a good internal consistency of the same. The internal consistency of the questionnaire for each subset of criteria, ERP vendor and ERP software package, was also evaluated to check if it was substantially different from each other. The results showed a moderate consistency with regard to items related to the vendor, Cronbach's Alpha = 0.689, and a good consistency for the software, Cronbach's Alpha = 0.763.

It should be emphasized that the internal consistency of the overall survey is considerably higher when compared to the consistency of each subset. The survey provides a measure that, in light of these results, can be considered fairly consistent. In order to understand if the questionnaire items are mutually independent, we analysed the correlations between them. We used the Spearman correlation since the items are mutually independent, we analysed the correlations between them. We used the Spearman correlation since the items are measured in qualitative ordinal scale. The results point to the nonexistence of statistical significance in the correlation between most of the items or, when assigned significance to the correlation, it appears to be too weak to be considered.

C. First survey

The first survey was carried out to a total universe of 1491 elements, which was obtained by removing the subsample of 80 elements used in validation. It were collected 138 valid responses, representing a overall response rate of 9.2%.

Table II presents the distribution by the kind of jobs the survey participants perform in their organizations. The table reveals that most of the participants are senior managers usually engaged in the process of acquisition of ERP systems.

<table>
<thead>
<tr>
<th>Job</th>
<th>Qty</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS manager</td>
<td>28</td>
<td>20.3%</td>
</tr>
<tr>
<td>IS staff/ technician</td>
<td>17</td>
<td>12.3%</td>
</tr>
<tr>
<td>IT business manager / IS consultant</td>
<td>76</td>
<td>55.1%</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>12.3%</td>
</tr>
</tbody>
</table>

The above numbers do not include the survey of the restricted sample that was carried on simultaneously.

By analysing the 138 valid answers collected, we realized that all criteria, with the exception of “market position/scale" and "Source code availability", achieve the two higher levels of five items scale, termed "important" and "essential". The criterion “market position/scale" was classified by 45% of the respondents as "something important", but more than 30% rank it as “important”. The criterion "source code availability" was considered as “of little importance” by 32% of the respondents, but 24% rank it as “something important” and 26% as “important".

Most of the criteria obtained the highest percentage for level "important". Five criteria were classified as essential by more than 45% of the respondents: technical team capability, technical support quality, function-fitness, security, and stability and recover capability. The criterion “function-fitness” has the highest rank with about 65% of votes as “essential”.

The lower scale level, called "irrelevant" obtained the maximum of 5.8% of the responses to the criteria "hardware requirements" and "source code availability". All the other criteria got less than 4% votes for "irrelevant" and eight of them did not got any vote on "irrelevant".

The results of the first restricted sample survey where quite similar to the described previously for the general sample survey. However, it should be emphasized that the criteria “market position/scale" and “source code availability” were classified as “important” by the restricted sample. Therefore, it was decided that all criteria are important to the decision process and should be maintained in the second survey to the restricted sample.

D. Second survey

It was performed a second restricted sample survey, according to the main characteristics of the Delphi [21], to allow the restricted sample elements to refine and reconsider their view. The request for the new survey included the answer of the respondent to the first survey and the criteria overall ranks obtained in the first criteria.

The questionnaire of the second restricted sample survey included two new questions of the two criteria that were proposed by the respondents of the first survey. This survey allowed verifying the consistency of the first results and the importance of these new.

Only some respondents, less than 30%, changed the assessment of some few criteria, so the consistency is very high when compared to the first survey. The two new criteria

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\(^1\) http://www.limesurvey.org/
included in the new questionnaire were ranked as “of little importance”.

V. ANALYSE OF THE RESULTS

In this section, we describe the tests performed over the results of the two surveys separately.

A. Analysis of the results of the first survey

To check whether, for each item, the results are similar between the restricted sample and the general sample, we performed the Mann-Whitney test with 95% of confidence. The results show that only four criteria have differences: “guarantees”, "consulting services", "customization", and "user friendliness". The restricted sample ranked higher the first three criteria, and the general sample ranked higher the last one criterion “user friendliness”.

It was carried out a chi-square test to check whether the size of the organization, indicated by the respondents in the beginning of the questionnaire, has some influence on the importance assigned to each criterion. The results show that only the "payment and financial terms " and "customization" criteria are dependent on the size of the company. The larger organizations rank both criteria with higher importance.

The Principal Component Analysis (PCA) reveals that the criteria "Portfolio" and "Financial condition" are a component of one component. The other criteria are grouped into components as shown in table III.

<table>
<thead>
<tr>
<th>Component</th>
<th>Nr. Items</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>C01</td>
<td>5</td>
<td>Technical team capability; Technical support quality; Function-fitness / module completion; Guarantees; Consultancy services</td>
</tr>
<tr>
<td>C02</td>
<td>4</td>
<td>Payment and financial terms; Operating system compatibility; Hardware requirements; Database engine compatibility</td>
</tr>
<tr>
<td>C03</td>
<td>2</td>
<td>Documentation quality; Market share / Scale of the vendor</td>
</tr>
<tr>
<td>C04</td>
<td>4</td>
<td>Consultancy cost; Integration support; Implementation ability; Customization</td>
</tr>
<tr>
<td>C05</td>
<td>5</td>
<td>Integration/middleware cost; User friendliness; Scalability and upgrade ability; Stability and recover capability; Security</td>
</tr>
<tr>
<td>C06</td>
<td>3</td>
<td>Hardware/infrastructure cost; Software licencing cost; Software acquisition cost</td>
</tr>
</tbody>
</table>

TABLE III. PCA SUMMARY

For each of these components, we measured the Spearman correlation and checked the existence of correlations between all the criteria of each component. The results demonstrate that highest correlation was 0.616, which cannot be considered very strong. Therefore, this test confirms the results of PCA.

B. Analysis of the results of the second survey

The Wilcoxon test for paired sample with 95% of confidence was used to evaluate if there was significance difference between the restricted sample responses to first survey and second survey, considering only the 28 questions used in the first survey questionnaire. The test results suggest that there are no significance difference between the first moment and the second moment. In fact, the worst p-value score obtained for this test was 0.06 and 0.10 for “Financial condition” criterion and “Hardware requirements” criterion respectively. The null hypothesis cannot be rejected for any criteria, so we must assume that the answers are the same in the two moments of evaluation.

Because there is no rejection of the null hypothesis, we decided to perform a linear regression analysis for each criterion, where the dependent variable was the value of the criterion in the second moment and the independent variable was the value assigned in the first moment. The results show that all the criteria for the constant may be zero and the worst value obtained for the constant independent variable was 0.816.

Because the coefficient of the independent variable and the value of the constant are close to one and zero respectively, we can accept that the responses are similar in the two moments. This confirms the consistency of the responses over time.

VI. CONCLUSION AND FUTURE WOKS

The results of the surveys do not represent any significant surprise and confirm the results obtained in the literature review. Even the four criteria that presented differences between the two samples are not a revelation: the general sample values "user friendliness" while the expert sample highlights the “guarantees”, "consulting services", and "customization". The other result that confirms our intuition if that the larger organizations rank "payment and financial terms" and "customization" criteria with higher importance than the smaller ones.

These results correspond to the first phase of a research project that aims to provide a framework and a tool to assess a set of alternative ERP software proposals in the context of Portuguese organizations. The next step will be to calculate the weight of each criteria based in the rank obtained by each one in the last survey. The weight of each subset, ERP vendor and ERP software package, will result from the aggregate weight of its criteria, according to the AHP method. Finally a software tool will be developed to help to use this framework in the selection of ERP software solutions.

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V. A. N. Everdingen, “Searching for ERP systems offering a perfect fit,” vol. 43, no. 4, pp. 0–5.


Dirigiendo el Esfuerzo de la Mejora de Procesos Software en Pymes

Leading the Effort of Software Process Improvement in SMEs

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Resumen—Las Pymes han conocido que la calidad de un producto software depende fuertemente de los procesos utilizados para su creación, sin embargo, aun cuando muchas de ellas están motivadas para poner en marcha iniciativas de procesos de software (SPI), no todas saben la mejor manera de hacerlo, debido a sus características especiales, como son presupuestos limitados donde su gestión es cuidadosa para asegurar su supervivencia en el mercado. Como resultado, la implementación SPI en las Pymes se ha convertido en todo un desafío, sobre todo porque su cultura de trabajo está inmersa en un entorno caótico y cambiante. En este trabajo se presenta un método para dirigir el esfuerzo de la mejora de procesos software en Pymes. Para lograr esto, se han adaptado actividades de la Metodología Goal Question Metric (GQM). Además, se presenta la experiencia de la aplicación del método propuesto para proponer mejoras en una Pyme.

Abstract—SMEs have known that software product quality depends heavily on the processes used for its development. However, even though many of them are motivated to implement software process improvement (SPI) initiatives, not all know the best way to do it, due to its special characteristics, such as limited budgets where the management is careful to ensure their survival in the market. As a result, implementing SPI in SMEs has become a challenge, especially since their work culture is undergoing a chaotic and changing environment. This paper presents a method for directing the efforts of software process improvement in SMEs. To achieve this, we have adapted the main activities of Goal Question Metric (GQM). Besides, it presents the experience of applying the proposed method to lead the effort to implement improvements in an SME

Keywords: Goal Question Metric; Mejora de Procesos; Pymes

I. INTRODUCCIÓN

En las últimas dos décadas las Pymes de la industria del desarrollo del software han crecido, fortalecido y hoy representan una pieza fundamental en este tipo de industria al punto de representar un sector económico de suma importancia en la mayoría de los países a nivel mundial [1,2,3,5,6]. A lo largo de este crecimiento las Pymes han conocido que la calidad de un producto software depende fuertemente de los procesos utilizados para su creación. Por lo tanto, este tipo de organizaciones están más consientes acerca de la mejora de procesos software (SPI) [5].

Sin embargo, aun cuando estas organizaciones están motivadas a implementar y/o mejorar sus procesos software, la implementación de SPI in Pymes se ha visto obstaculizada debido a los presupuestos limitados para invertir en la mejora de sus procesos software, así como, a la carencia de conocimiento para dirigir su esfuerzo en la implementación en SPI [2,4,5,7].

Por lo tanto, el objetivo de esta investigación es presentar un método que permita a las Pymes identificar mejoras para dirigir el esfuerzo para las iniciativas de proyectos en SPI.

Este artículo está estructurado de la siguiente manera: En la sección 2, se describe brevemente la metodología GQM; en la sección 3, se describe el método propuesto con la adaptación de las actividades principales de GQM; en la sección 4 se presenta un caso de estudio aplicado a una Pyme, y finalmente, en la sección 5 se presenta el informe de Propuestas de Mejora y, finalmente en la sección 6 se presentan las conclusiones.

II. GOAL QUESTION METRIC

En esta sección se presenta una breve descripción de la metodología Goal Question Metric (GQM). GQM consiste de 3 principales actividades [9]:

1) Definición de los objetivos de la organización.
2) Definición de las preguntas asociadas a cada objetivo.
3) Definición de las métricas para responder las preguntas de manera cuantitativa.

Este trabajo ha sido patrocinado por CIMAT Unidad Zacatecas, México.

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El establecimiento de GQM es el resultado de muchos años de experiencia práctica y de investigación académica el cual fue desarrollado por V. Basili y Weiss D [9]. GQM ayuda a: 1) Alinear las métricas con los objetivos de negocio de la organización y las metas técnicas, 2) Mejorar el proceso del software, 3) Gestionar los riesgos, 4) Mejorar la calidad del producto. La metodología GQM se define como un árbol jerárquico (véase la Figura 1), los objetivos tienen la más alta jerarquía. Para cada objetivo se definen una serie de preguntas.  

Cada pregunta tiene a su vez un conjunto de medidas con el fin de responder a las preguntas cuantitativamente, una métrica puede responder a las preguntas de los diferentes objetivos.

GQM es una metodología muy útil para la mejora de procesos de software debido a su madurez y flexibilidad para ser aplicado en cualquier entorno organizacional [12-15]. Por ejemplo GQM se ha utilizado para mejorar los procesos en organizaciones tales como: a) Ericsson [12] donde se mejoró en los procesos de gestión del cambio y de procesos relacionados a la ingeniería de requisitos, b) Nokia [13] muestra la identificación de mejoras en sus procesos de desarrollo y mantenimiento de software; además, GQM también se ha utilizado en campos fuera del entorno desarrollo de software [14-16].

III. MÉTODO PROPUESTO

El objetivo del método propuesto es ayudar a las Pymes a identificar mejoras para dirigir su esfuerzo en la mejora de procesos software. Por lo tanto, las actividades establecidas en este método han sido combinados con los pasos principales de GQM (Véase sección 2). La Figura 1 muestra un esquema general del método propuesto.

A. Conocer el entorno.

El propósito de esta actividad es extraer el conocimiento tácito mediante la realización de entrevistas con la finalidad de conocer la situación real de la organización. Para lograr esto, se debe entrevistar a la alta dirección (CEO) ya que es quien ha estructurado y fundado la organización. La entrevista debe ser semi-estructurada y registrada en medios electrónicos. La Tabla 1 muestra las subactividades que se deben realizar para esta actividad.

B. Analizar la información.

El objetivo de esta actividad es identificar y establecer la estructura y cultura de trabajo de la organización, así como detectar las necesidades y poder establecer objetivos preliminares. La Tabla 2 muestra las subactividades de esta actividad.
C. Aplicar pasos de GQM.

El propósito de esta actividad es analizar la información obtenida en la actividad 2 con la finalidad de poder establecer los objetivos formales de la organización. La Tabla 3 muestra las subactividades de esta actividad.

<table>
<thead>
<tr>
<th>Tabla 3. Subactividades: Aplicar pasos de GQM</th>
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<tr>
<td>Subactividades</td>
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<tr>
<td>Establecer los objetivos de negocio</td>
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<tr>
<td>Establecer preguntas</td>
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<tr>
<td>Establecer métricas</td>
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<tr>
<td>Aprobar objetivos, preguntas y métricas</td>
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D. Informe de propuesta de mejora.

El propósito de esta actividad es analizar los objetivos, preguntas y métricas con la finalidad de informar sobre las propuestas de mejora con respecto a modelos y estándares de calidad adecuados para el logro de los objetivos establecidos.

IV. CASO DE ESTUDIO

En esta sección se presenta el caso de estudio del método propuesto llevado a cabo en Has-It con la finalidad de dirigir su esfuerzo en la mejora de sus procesos software.

La empresa HAS-IT es una Pyme mexicana, dedicada al desarrollo de aplicaciones FPGA (Field Programmable Gate Array) y sistemas embebidos, brindando soluciones integrales pensadas en la generación de productos específicos y diseños a la medida de cada empresa. Además, ofrece servicios de asistencia y capacitación en el uso y explotación de nuevas tecnologías.

Actualmente en la organización laboran 8 empleados, cubriendo las siguientes áreas de la empresa: Gerencia empresarial, Producción, Diseño, Software Embebido, Micro controladores, Diseño PCB (Printed Circuit Board), e Investigación.

A. Conocimiento del Entorno y análisis de información

De acuerdo a las subactividades establecidas para establecer el conocimiento del entorno y el análisis de la información obtenida por las entrevistas se obtuvo el conocimiento del entorno actual de Has-IT y sus objetivos preliminares. Para lograr esto, se establecieron cuestionarios y fechas para las entrevistas para llevarse a cabo con el CEO de la organización. Como resultado se estableció la situación actual, las necesidades y los objetivos preliminares.

La situación actual identificada en Has-It es que no cuenta con algún modelo o estándar de calidad implementado. Sin embargo, por parte de la gerencia, se ha llevado un curso general de ITIL, del cual solo se ha implementado la parte de CAB (Change Advisory Board) con la finalidad que cada jefe del área de producción esté de acuerdo y conozca los cambios dentro del proyecto.

Dentro de los objetivos preliminares que se detectaron se encuentran:

1) Conocer los procesos de cada área.
2) Conocer el nivel de satisfacción del cliente.
3) Controlar los cambios de requisitos.
4) Mejorar el proceso de gestión de proveedores.
5) Establecer un área de aseguramiento de la calidad de los productos.

B. Inclusión de pasos de GQM

Una vez detectada la situación actual, necesidades y los objetivos preliminares se formalizan los objetivos, preguntas y métricas a través de las 3 actividades principales de GQM. Los objetivos establecidos son:

1) Establecer un proceso de gestión de cambios para conocer el objetivo de cada cambio y aumentar el desempeño de todos los miembros del equipo.
2) Establecer un proceso de gestión de proveedores para mejorar la planificación de las actividades a lo largo del ciclo de vida del un proyecto para una gestión adecuada del proyecto.
3) Evaluar la calidad de los productos y/o servicios para conocer la satisfacción del cliente con la finalidad de controlar los requisitos por parte del equipo de trabajo.
4) Asegurar la calidad de los productos entregados para registrar datos históricos con lo que se conocerá los históricos de calidad de los productos elaborados por la organización.

Establecimiento de preguntas: De acuerdo a los objetivos establecidos las siguientes preguntas fueron establecidas:

**Objetivo 1:**

1) ¿Cuál es el estado actual de cada requisito?
2) ¿Cuál es el nivel de estabilidad de los requisitos?
3) ¿Por qué se realiza un cambio en los requisitos?
4) ¿Cuál es el costo de cambiar los requisitos?
5) ¿El número de cambios de requisitos es manejable?
6) ¿El número de cambios de requisitos se decrementó con el tiempo?
7) ¿Cuántos requisitos son afectados por un cambio en un requisito?