Customer requirements based ERP customization using AHP technique

INTRODUCTION

An enterprise resource planning (ERP) system can be considered as a solution for enterprises to standardize their business processes. Many organizations invest in ERP under the assumption that the implemented ERP system will deal with their interrelated business goals, such as achieving their financial targets quicker, managing and streamlining their operational processes, and improving their business forecasting. For individual companies, however, the implementation of ERP systems involves great challenges, and reaping the benefits from ERP is far from straightforward (Schubert and Williamson, 2011; Eckartz et al., 2012). Any successful ERP implementation requires a complete fit between the ERP system and the business processes it supports (Rotheberger et al., 2009; Parthasarathy and Anbazhagan, 2007, Luo and Strong, 2004). A major roadblock in for many ERP-adopting organizations to realize the benefits of ERP is the customization of the built-in business process logic and functionality of the package (Momoh et al., 2010).

In this paper, the term 'customization' refers to changes or additions to the functionality available in the standard ERP software (Light, 2001). It does not mean the 'switching on and off' of functionality that is available in the package, which is sometimes called 'ERP system configuration' (Keller and Teufel, 1998). The objective of customization in ERP implementations is to achieve a fit between the ERP system and the business processes that the system supports. Past research studies on ERP projects reveal that companies should be extremely careful with ERP customization. The reason is that both over-customization and under-customization pose a variety of risks to ERP implementation. Over-customization usually results in an ERP system with a reduced degree of functional integration and, in turn, has an increased risk of failure to reap the full benefits of this packaged software (Ghost et al., 2002; Serano and Sarriegi, 2006; Tiwana and Keil, 2006). Under-customization

yields an ERP solution that is inflexible to the implementing enterprise and does not meet all of their business requirements (Zach et al., 2012; Ahmad et al., 2012; Seethamraju et al., 2013).

For the ERP implementation team to be able to make well-grounded decisions on the degree of customization for the ERP system, they need to explore and evaluate the different ERP customization choices (Rotheberger et al., 2009; Eckartz et al., 2012; Sarfaraz et al., 2012; Amid et al., 2012). While some approaches and frameworks (e.g. Brehm et al., 2001; Luo and Strong, 2004; Soh and Sia, 2004) have been proposed to help with ERP customization evaluation, most of them treat customization from a business-IT alignment perspective, from an organizational theory perspective, or from a technical/code level perspective. In this paper, building upon published research, we design a new ERP customization framework for evaluating ERP implementation choices from the requirements engineering perspective.

Taking the customer's requirements as the starting point, this framework helps evaluate the various ERP customization choices for the implementing organization. The framework captures three dimensions of the customer's requirements, namely the application, the process and the design, which are used to identify the possibilities to fine-tune both the ERP-adopter's business processes and the ERP system itself. We note, however, that the framework does not determine decisions for the management; rather it provides the possibilities for customization and indicates the level of software and business process customization required during the ERP implementation.

In this study, we apply Analytical Hierarchy Process (AHP) to the ERP customization framework to prioritize ERP implementation choices and enable management decision-making with regard to customization. As this framework views three dimensions of the customer's requirements (namely the application, the process and the design), the AHP technique yields various prioritized customization possibilities that would definitely suit the ERP system's application, process and design. The application of the AHP to the proposed ERP customization framework is

demonstrated in a case study that we carried out in an organization involved in ERP implementation.

This paper makes contributions to both theory and practice. From a theoretical standpoint, it extends the framework of Luo and Strong (2004) by providing a three-dimensional view of the customer's requirements and by applying the AHP method. We build our extended framework on software engineering and requirements engineering foundation to explicitly view customization as grounded on the customer's requirements. This is a step that closes an important gap in knowledge, as until now the requirements and software engineering perspective of ERP customization has by and large remained unaddressed (Sarfaraz et al., 2012; Chen et al., 2009; Françoise et al., 2009; Parthasarathy et al., 2007; Luo and Strong, 2004), despite being acknowledged as necessary (Kumar et al., 2012; Robertson et al., 2012; Alexander and Beus, 2011; Daneva et al., 2006). As we will see in the next section, published studies treated ERP customization either from a narrow technical perspective or from a broader organizational perspective, and whatever empirical research has been reported focused primarily on customization problem analysis and not so much on solution design. The framework and its joint use with the AHP process represent a solution to evaluating and prioritizing ERP customization requirements.

From a practical perspective, the approach presented in this paper identifies various customization possibilities for customers as well as ERP systems. It also makes the ERP implementation team conscious of the options available to them and their relative priorities. We found this approach to be a good alternative to ERP clients as they no longer have to accept whatever customization choices are recommended to them by ERP vendors and consulting partners. Customers could achieve transparency in the evaluation and prioritization of their ERP customization scenarios and easily subject to scrutiny any hasty recommendation for customization.

BACKGROUND AND RELATED WORK

This section provides a background of ERP customization as a phenomenon and summarizes related empirical research publications on approaches and frameworks for the evaluation of customization. In the past decade, much research effort has gone toward understanding the reasons for customization (Light, 2001; Zach and Munkvold, 2012; Kahkonen et al., 2013), the factors that influence customization (Hwang et al., 2011), the problems that it often creates (Ghost et al., 2002; Light, 2001; Amid et al., 2012) and the risks associated with customization decisions during ERP implementation (Botta-Genoulaz et al., 2005).

To identify more recently published related work on ERP customization, and to do so in a more systematic fashion (Websters and Watson, 2002), we searched the Scopus digital library (www.scopus.com). We complemented this search by looking in the papers that were included in five recently published systematic literature reviews on ERP topics related to ours (Kähkönen and Smolander, 2013; Shaul and Tauber, 2013; Momoh et al, 2010; Jadhav and Sonar, 2009; Moon, 2007). We chose these literature reviews because they touched upon the phenomenon of ERP customization and also because they provided examples of and empirical evidence on the challenges related to customization in various kinds of projects and ERP-adopting organizations.

For the purpose of this section (namely to provide background and related work), we selected 13 references that published frameworks and approaches to ERP customization and the perspectives that the authors of these frameworks and approaches chose to take in their analyses. These sources indicated that, if approaches and frameworks for evaluation of customization choices are employed in ERP-adopting organizations, this would then improve managers' and stakeholders' decision-making with regard to customization during ERP implementation. Below (Table 1), we first present some examples of proposed frameworks by providing details on the theoretical perspective taken in the design of each. After this, we will draw some implications from this related work for our research.

Framework/Approach to customization evaluation	**Theoretical perspective**
Brehm et al, 2001	Technical tailoring perspective
Luo and Strong, 2004	Resource-based perspective and capability-based perspective
Soh and Sia, 2004	Institutional perspective, organization adaptation perspective
Morton and Hu, 2008	Structural contingency theory perspective
Akkiraju and Van Geel, 2010	Artifact-centric cost estimation perspective
Pries-Heje, 2010	Socio-technical theory
Qin and Wang, 2010	Quality defect perspective
Haines, 2010	Cost ownership perspective
Uwizeyemungu and Raymond, 2012	Resource-based perspective
Sarfaraz et al, 2012	Package selection perspective
Zach and Munkvold, 2012	Technical customization taxonomy perspective
Ng, 2013	Perspectives of system fit, user attitude and acceptance, maintenance and upgrade cost
Saravanamuthu et al., 2013	Ethics, social learning and problem solving perspective

Table 1. Summary of related work and theoretical perspectives applied

Brehm et al., (2001) develop a topology of technical customization categories that reflect essential aspects of ERP tailoring (at code, table and interface level). The authors define these categories by adopting technical perspectives, e.g. a maintenance one.

Luo and Strong (2004) were the first to propose a framework that unites the business processes of the enterprise with their ERP system. The goal of this framework is to help organizations understand which customization options are available and which of these are feasible given an organization's capabilities. The framework rests on the idea of combining customization options with the technical and process change capabilities required for system and process customization.

Soh and Sia (2004) define customization evaluation as a problem of misalignment between the business and the underlying technology that supports its operations. They use institution theory and take an organizational adaptation perspective to design a framework that helps to identify the misalignment between the organization and the system.

Morton and Hu (2008) treat customization as part of examining the issue of fit between organizational structures and ERP systems. They propose a framework of contingency fit between ERP and organizational types. To design it, structural contingency theory is used to identify a set of dimensions of organizational structure and ERP system characteristics that can be used to gauge the degree of fit.

Akkiraju and Van Geel (2010) treat ERP customization from a cost estimation perspective by combining an artifact-centric approach and linguistic analysis approach. The authors adopt a technical perspective on counting business objects in ERP projects that use Service-Oriented Architecture design style.

Prise-Heje (2010) takes the socio-technical theory as a lens through which to explore the socio-technical misfit in ERP-adopting organizations. The author uses a four-layer metaphor-based concept to understand ERP implementation, and customization as part of it, as a cooperative socio-technical design process. The author concludes that the joint optimization of social and technical sub-systems would very seldom be realized.

Haines (2010) views ERP customization from a cost ownership perspective. He treats customization as a specialization of a business asset. The author uses exploratory case study data to come up with a framework of influences on ERP module customization. The framework includes 12 constructs grouped in four categories: strategy, institution, project and system.

Qin and Wang (2010) adopt a quality defect perspective to come up with an algorithmic model for predicting the quality of a customized ERP system. The authors confront the assumption in traditional quality prediction models regarding the presence of historical databases with defect information collected from past similar projects. The authors argue that the use of customization in ERP projects contributes to dissimilarity across projects and renders such databases less useful. They develop an algorithm that uses customization information with more uncertainty than traditional approaches can handle.

Most recently, using the resource-based view as a theoretical lens, Uwizeyemungu and Raymond (2012) developed a framework that establishes a relationship between the essential characteristics of an ERP system (termed 'ERP capabilities') and the contribution of the system to organizational performance.

Sarfaraz et al (2012) developed a framework to support managers involved in ERP package selection. This framework deploys fuzzy analytical hierarchy process (FAHP) to analyze the match between the organizational needs and the ERP system.

Zach and Munkvold (2012) used an exploratory study on ERP customization in four organizations to identify the taxonomy of system customization types and a catalogue of reasons to use each type. Systems customization types are classified in two categories, namely 'prior to going-live' and 'after going live'.

Ng (2013) developed a model for predicting the benefits and cost of subsequent maintenance and upgrades to the system. This author indicated that, although ERP customization is likely to create integration and compatibility problems with the system, overall the ERP users accept the system better as the add-on helps to improve their job performance. Ng also states that "even though having a custom development does create additional costs in this case study; this does not necessarily cost more than not having it". In the same vein, having an idiosyncratic system may actually transfer a lot of benefits to the company. We found this to be one of the few studies showing why custom development is favored by SMEs.

Furthermore, Saravanamuthu et al., (2013) position ERP customization within the broader context of society than in the realm of an ERP-adopting organization. These scholars treat the customization phenomenon as one happening in a complex

ecosystem of business and system elements. They take an Eastern philosophical perspective in their reasoning and argue why it should be incorporated into the Western-dominated systems design arena. Although the paper does not include any empirical application of the proposed framework, we considered it worthwhile including it in our section of related work because it indicates a less explored, yet well-justified, reasoning of ERP customization and the risk it brings.

Our review of the sources in Table 1 indicates that:

- the evaluation of customization is treated either in a relatively narrow technical manner (e.g. Brehm et al., 2001; Akkiraju and Van Geel, 2010; Qin and Wang, 2010), or in a very broad organizational context (e.g. Soh and Sia, 2004; Prise-Heje, 2010).
- The technical perspective usually helps solve an important, yet very specific, technical problem e.g. cost estimation, quality defect prediction, and the tracing back of defects to system design activities. To the best of our knowledge, we could find no study on the joint evaluation and prioritization of customization scenarios that treats it as a technical problem but also positions it within its organizational requirements context and approaches it from a requirements and software engineering perspective. Such a perspective is necessary because customization during ERP implementation originates from the customer's requirements (Kumar et al., 2012; Robertson et al., 2012; Alexander and Beus, 2011; Daneva et al., 2006) and usually has implications for the whole systems delivery process.
- The managerial perspectives, e.g. the structural contingency theory in Morton and Hu (2008), the institutional perspective in Soh and Sia (2004), although helpful for shaping our understanding of the ERP customization phenomenon, leave unanswered the question of how to translate the high level business requirements into application and design requirements in such a way that allows for the evaluation and prioritization of the various possible arrangements of the customization options available in an ERP package.

The observations in the bulleted list above indicated a gap and motivated us in initializing research efforts toward closing it in a systematic fashion. For project managers who consider the ERP projects from a software engineering and systems delivery perspective (Light, 2001), a pragmatic framework would mean one that can translate the high level organizational goals, needs and requirements into more detailed requirements at application, architecture and design level (Parthasarathy et al., 2007). Such a framework could be used to evaluate the possible customization scenarios once an ERP package has been chosen. Ideally, it can also be used to prioritize the customization choices based on stakeholders' requirements. In the next section, we present our framework for ERP customization, after which we complement it with the AHP technique to prioritize customization choices.

THE ERP CUSTOMIZATION FRAMEWORK

The ERP customization framework designed in this study is based on three types of sources:

(i) the various customization approaches for ERP described by Luo and Strong (2004);

(ii) the previously published empirical studies on requirements engineering for ERP (Daneva and Ahituv, 2011; Daneva and Wieringa, 2006; Daneva, 2004; Keller and Teufel, 1998), and

(iii) the previous research works on ERP from a software engineering perspective (May et al., 2013; Tchokogué et al., 2005; Kumar et al., 2003; Robertson et al., 2012; Alexander and Beus, 2011).

Drawing upon these sources, in the proposed ERP customization framework (shown as Table 2), the requirements are broadly classified into three categories, namely the Application Requirements (AR), the Process Requirements (PR) and the Design Requirements (DR).

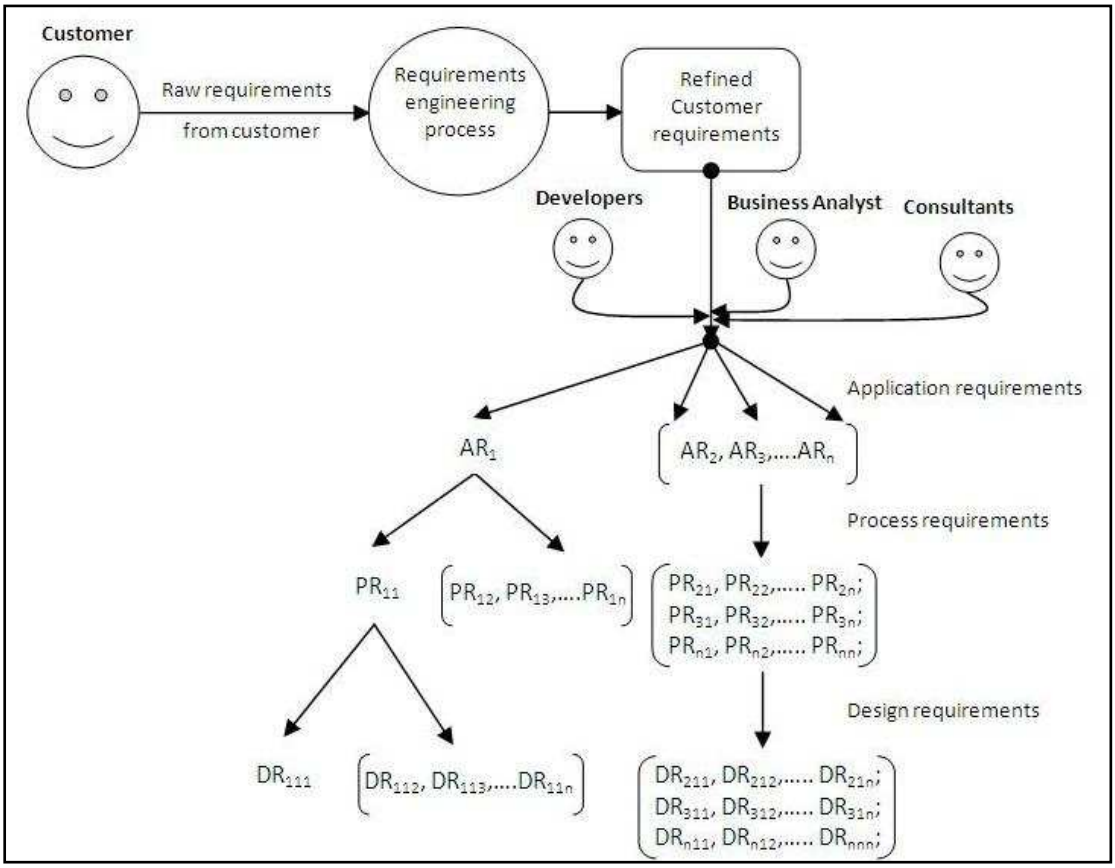

Figure 1 Derivation of application, process and design requirements for customer

The ARs are those that are required for the software to meet the customer's requirements. The PRs are those functions/tasks that are required to fulfill the application requirements. For each AR, a set of corresponding PRs are identified. The DRs are those requirements/design constraints that are required to execute the process requirements. The DRs are the requirements to be fulfilled during the software design stage. For each PR, a set of DRs are prepared.

The implementing organization usually provides only the basic 'raw' requirements at the start of the ERP implementation. The term 'raw requirements' means those requirements that are stated by the customer in the request for proposal document, or in the high-level business requirements document that is prepared at the initial stage of the project. These requirements typically reflect the problem statement of the customer. The ARs, the PRs and the DRs are derived from these raw requirements by the developers in coordination with the ERP consultants.

Unlike in other IT projects, where a company may well have their business analyst/requirement specialist (or internal team of analysts) collect the requirements from the customer and perform the requirements engineering process to finalize the requirements, in the case of ERP, the raw requirements of the customers are analyzed by a project team including both the company's IT staff and external consultants responsible for the ERP implementation. They work together and generate a set of ARs, PRs and DRs. The process flow involved in the derivation of the application requirements, the process requirements and the design requirements from the basic customer requirements are illustrated in the Figure 1.

For example, the ARs may look like the following: (AR-1) "Getting updated contact details from the existing alumni". For AR-1, there can be one or more process requirements (PRs). One such process requirement corresponding to AR-1 is given below: (PR-11) "To display the existing contact details of the alumni available in the alumni database". Furthermore, for the given process requirement (PR-11), the corresponding design requirement is: (DR-111) "To check the authenticity of the alumni using virtual keyboard".

The ERP customization is an integral part of ERP implementation and is usually handled in two ways, namely by means of the business process customization and the ERP system customization (Luo and Strong, 2004). The primary goal of customization in ERP implementation is to ensure that the company's requirements match with the resulting ERP solution (Rotherberger et al., 2009). This can be achieved either by changing the existing business processes of the enterprise to those of the ERP system, or vice versa. The decision on the type of customization and the roadmap to execute it during ERP implementation is basically a difficult task for the management and the ERP implementation team.

Table 2 presents our framework. Here, the cell "No customization (ANC)" refers to the business process that fits the system process and in which no customization is necessary. The cell "Application Adaptation (AIC)" deals with the ideal system process and business processes which are close to it. The cell "Application Conversion (ARC)" refers to the business process that is far from the system process. The cell "Fit System to Process (PNC)" indicates that business

process change is not necessary and it is better to fit the system process to the business process. The cell "Mutual Adaptation (PIC)" is meant for making minor modifications to both the system process and the business process. The cell "Fit Process to System (PRC)" means minor system process changes are necessary and can be achieved by redesigning the business process to system process.

Customer's Requirements	Customization Options		
	No Change (NC)	**Incremental Change (IC)**	**Radical Change (RC)**
Application Requirements (AR)	No Customization (ANC)	Application Adaptation (AIC)	Application Conversion (ARC)
Process Requirements (PR)	Fit System to Process (PNC)	Mutual Adaptation (PIC)	Fit Process to System (PRC)
Design Requirements (DR)	Design reflects the Processes (DNC)	Design fine-tuning and Process Adaptation (DIC)	Re-Designing and Process Reengineering (DRC)

Table 2. ERP Customization Framework

In the ERP customization framework, the design requirements of the customer are analyzed in three stages commencing from "No change in design (DNC)", then an "Incremental change to design (DIC)" and finally, "Radical changes to design (DRC)". At first, if the design reflects the processes, then the ERP system requires no changes. This is referred in the framework as "DNC". The cell "DIC" refers to the state, where some process requirements are not fully reflected in the design and a fine-tuning of both the system design and the corresponding processes becomes mandatory. The cell "DRC" involves completely re-designing the system and the process re-engineering. It is observed that, the cell "DRC" in the framework is the least preferred in ERP implementation as it involves total revamp of business and system processes (Luo and Strong, 2004; Parthasarathy and Anbazhagan, 2007).

COMPLEMENTARY USE OF THE FRAMEWORK AND AHP PRIORITIZATION

In our research, we apply the AHP approach introduced by Thomas L. Saaty (Saaty, 1980) to our customization framework. The AHP is a methodology for multi-criteria analysis of choices and decision-making that enables decision makers to account for the interaction of multiple factors in complex situations. The AHP process requires the decision makers to develop a hierarchical structure for the factors which are explicit in the given problem and to provide judgments about the relative importance of each of these factors to specify a preference (Benítez et al., 2012, Delgado-Galván et al., 2014, Zhang et al., 2014) for each decision alternative with respect to each factor. It provides a prioritized ranking order indicating the overall preference for each of the decision alternatives.

The AHP process is deemed most useful in situations where teams of experts are working on complex problems, especially those with high stakes, involving human perceptions and judgments, and whose resolutions have long-term repercussions (Bhushan et al., 2004). It has unique advantages when important elements of the decision are difficult to quantify or compare, or where communication among team members is impeded by their different specializations, terminologies, or perspectives.

Decision situations to which the AHP was applied include (Wang et al.,1991; Ernest et al., 2001): (i) Ranking, that is to put a set of alternatives in order from most to least desirable, (ii) Prioritization, that is about determining the relative merit of members of a set of alternatives, as opposed to selecting a single one or merely ranking them, (iii) Resource allocation, that is to apportion resources among a set of alternatives, (iv) Benchmarking, that is to compare the processes in one's own organization with those of other best-of-breed organizations, (v) Quality management, that includes dealing with the multidimensional aspects of quality and quality improvement and (vi) Conflict resolution, that is to settle disputes between parties with apparently incompatible goals or positions (Saaty et al., 2008). Some of the real-life large-scale applications of AHP include its use in integrated manufacturing (Putrus, 1990), in the evaluation of technology investment decisions

(Boucher et al 1991), in flexible manufacturing systems (Wabalickis, 1998), in layout design, (Cambron et al., 1991), in business management (Delgado-Galván et al., 2014), and also in graduates' career decision-making (Zhang et al., 2014).

Specifically in the area of ERP, the AHP process has been applied as part of solution and decision-making frameworks to solve various problems related to ERP selection (Silva et al., 2013; Méxas et al., 2012), to measurement of ERP implementation readiness (Hidayanto et al., 2013), to evaluation of critical success factors (Rouhani et al., 2013; Chang et al., 2012), to performance evaluation (Chen, 2012) and to risk evaluation in ERP maintenance (Salmeron and Lopez, 2010).

Recently, Sarfaraz et al., (2012) also applied a fuzzy logic-based AHP method to the customization framework of Luo and Strong (2004) for evaluating ERP customization choices. This wide use of AHP in the ERP domain encouraged us to consider it for inclusion in this research. However, in contrast to Sarfaraz et al., (2012) who used an AHP variant that rests on fuzzy logic, we opted for the original AHP process as presented by Saaty (1980) because of its flexibility and the availability of mathematical axiomatic principles and techniques to obtain group preferences and priorities (as also pointed out by Delgado-Galván et al., 2014). More in detail, our choice was motivated by the fact that the original AHP method requires as input pieces of data that could be relatively easily available in companies. In contrast to this, fuzzy logic-based variants of the AHP method put specific requirements on the input parameters that are fed into the AHP rules, for example estimating the degree of uncertainty associated with a specific parameter.

The overall approach of AHP is to decompose the total problem into smaller sub-problems in such a way that each sub-problem can be analyzed and appropriately handled from a practical perspective in terms of data and information. For the purpose of this decomposition process, the AHP uses a hierarchy that in fact deconstructs the problem into its component elements, groups the elements into homogeneous sets and arranges them hierarchically. Based on the hierarchical model, the AHP provides a method to assign numerical values to subjective judgments on the relative importance of each element and then to synthesize the judgments to determine which elements have the highest priority.

The overall objective of decomposition of the total problem into several levels is to enable pairwise comparisons of all the elements on a given level with respect to the related elements in the level just above. The AHP provides a method to assign numerical values to subjective judgments on the relative importance of each element and then to synthesize the judgments to determine which elements have the highest priority. The solution process consists of three stages:

(i) Determination of the relative importance of the attributes;

(ii) Determination of the relative importance of each of the alternatives with respect to each attribute; and

(iii) Overall priority weight determination of each of these alternatives.

In this study, the AHP approach is used to prioritize the ERP customization choices using the framework, as shown in Table 2. There we can see that the AHP provides nine prioritized customization options on the basis of the priority value obtained by this method for each cell in the framework. The AHP advocates the comparison of two requirements at one moment. Below, we describe the steps of the AHP:

Step 1.Choose the requirements to be prioritized.

Step 2.Set the requirements into the rows and columns of the n x n AHP matrix.

Step 3.Perform a pairwise comparison of the requirements in the matrix according to a set of criteria.

Step 4.Sum the columns.

Step 5.Normalize the sum of rows.

Step 6.Calculate the row averages.

THE CASE STUDY: APPLICATION OF THE FRAMEWORK AND THE AHP TECHNIQUE

The purpose of the proposed customer-centric ERP customization framework is to help the ERP implementation team to explore the different feasible customization options. As such, the framework is set to provide a way for choosing the customization options based on the customer's requirements. According to this

framework, this should involve determining the magnitude of changes desired in the customer's requirements based on three dimensions, namely application, process and design. Only then it is possible to select a feasible cell in the framework that matches the customer's requirements with the chosen ERP system. In this study, we illustrate the use of the framework by means of analyzing the ERP system implementation at a mid-sized company in the manufacturing sector.

Our evaluation of the proposed framework and its complementary use with the AHP technique was planned by using a case study research method (Yin, 2008). Our choice for this research methodology is justified by our research interest and commitment to exploring a real-life phenomenon in the context within which it occurs. As Bensabat et al., (1987) suggest, a case study is a particularly suitable research method for situations in which (1) researchers study socially constructed processes in systems development projects and seek to analyze the practice, and (2) researchers want to answer 'how' and 'why' questions and comprehend the nature and the complexity of the processes of interest. In our exploratory case study, we expected to get practitioner-specific judgments and preferences of customization requirements at application, process and design level.

Below, we describe our research process, its execution and the results that we obtained.

Research Process

Our case study research is exploratory in nature. Its goal is: (i) to apply the framework in a practical setting so that we can demonstrate for readers the results one could expect and (ii) to learn from its application.

We executed the case study by carrying out the following steps: (1) Recruit practitioners in a case study organization to help collect data, (2) Carry out the interviews to define preferences with representatives of two companies – a vendor and a client organization that both work on an ERP project; (3) Use the framework and run the AHP method, (4) Analyze the findings; (5) Write up the results.

As indicated in the Introduction, our case study includes two Indian companies: a vendor that specializes in providing ERP consulting and implementation services to mid-sized organizations, and a client organization that is a mid-sized

company in the manufacturing sector. The client is a leading producer of copper components and brazed copper assemblies for use in the air conditioning and refrigeration industries, that decided to go for ERP implementation. With revenues exceeding $5 million, the company (client) is a make-to-order shop with more than 100 employees, producing parts to individual customer specifications and prints. Prior to implementing the ERP, the company faced a problem familiar to many manufacturers, namely scheduling. The case study company was chosen for its typicality in the Indian mid-sized make-to-order production sector. Below, we provide background information on the case study organization and the practitioners that participated in the case study.

Context and Participants

In the year before the case study took place, the ERP client organization experienced challenges in running its existing business processes by using its existing systems. More specifically, customers were demanding shorter lead times and the company's existing ERP system was not capable of providing the information necessary to respond quickly. As a result, the company was losing business. The company was also moving their equipment away from manual operation to automation and they required a system that could schedule efficiently and had machine loading capability. It was imperative for the company to view their shop floor load at any point in time, allowing them to determine where potential problems existed and to create corrective solutions on the production line before slowdowns occurred. The management of the company contemplated rewriting their existing system in-house while they searched for other system solutions. Then they learned about the ERP system offered by the ERP vendor, referred in the paper as 'PRO'. They found that the PRO's ERP product would offer a complete business solution.

A team of fifteen practitioners from the ERP project contributed to our exercise. They all were considered experts in their respective professional fields and as such they were involved in ERP implementation to evaluate the feasible customization options available to them. Each expert had at least a decade of experience in implementing information systems. All of them had prior professional experience in ERP implementations varying from small to mid-sized organizations, to

very large ones. They also had in-depth knowledge of the business domain and the enterprise system implementation issues specific to it. In fact, they had also worked with traditional manual systems.

Six out of the fifteen experts were from the client organization and nine were from the vendor's side. The roles of the experts from the client's side were to define the business processes and deliver solutions through an integrated information system such as ERP. Three of the six experts were primarily with the business process management playing the role of business analysts and the other three were part of their management information system team and were considered as technical consultants. Five of the experts from the vendor's side were project technical team members and the other four were senior functional consultants.

The case study participants were selected by the first author based on his knowledge about their typicality. To ensure diversity of perspectives, the first author included practitioners that have various roles in the project; however who shared common settings and a professional background in the industry sector of the case study company (Daneva and Ahituv, 2011).

The experts were supplied with the scale for the pairwise comparison table (Saaty, 1980), as shown in the Table 3. They used this table to determine their degree of preference for the various attributes that serve as inputs to the 3 x 3 AHP matrices. Factors such as existing business processes in the implementing enterprise, the capabilities of their technical team and employees, top management involvement, their legacy system, hardware and software configurations on hand, expected project duration and end user training, were all considered by these practitioners while choosing the degree of preference for various attributes.

Degree of preference	**Definition**
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred
2, 4, 6, 8	Intermediate preferences between the two adjacent judgements
Reciprocal of the above non-zero numbers	Assuming L and J are both attributes in an AHP matrix 'A', if an attribute L in the matrix is assigned

	one of the above non-zero numbers when it is compared with another attribute J in the same matrix 'A', then J will get the reciprocal value when it is compared with L.

Table 3. AHP Pairwise Comparison

Our case study participants were asked to provide input to the 3 x 3 AHP matrices A, B, C and D given in Figure 2 below.

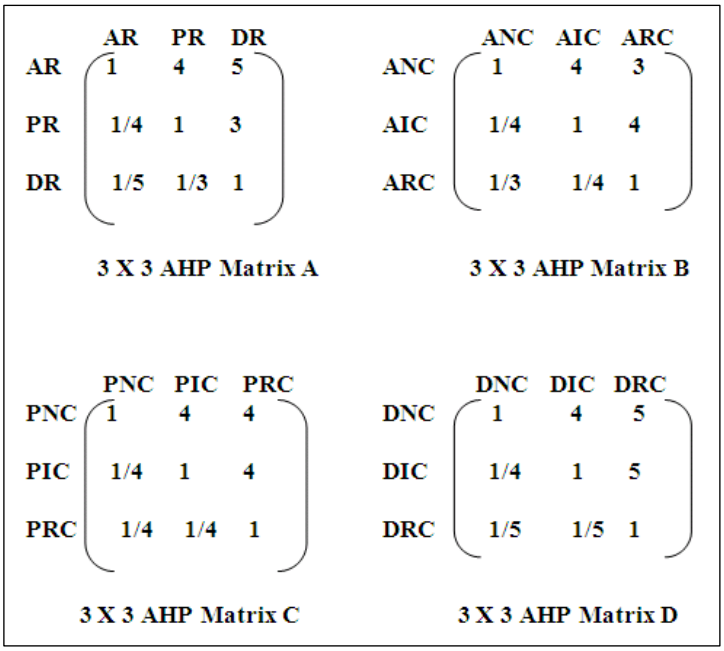

Figure 2 "3 x 3 AHP Matrices"

Matrix A represents the input values to compute relative priorities of the major attributes namely the ARs, the PRs and the DRs with reference to customization. Matrix B, Matrix C and Matrix D represent the input values for the three sub-attributes that are related to each major attribute and that are needed for computing the inter-criterion priority weights. The concrete input values in the matrices B, C, and D were provided by the practitioners for the ERP customization framework using the Table 3.

Each practitioner gave their degree of preference in the range 1 to 9, for every two attributes. For example, in comparing the attributes AR and PR shown in 3 x 3 AHP Matrix A, the degree of preference – that is, the input value given by the practitioner, is 4. Each comparison is done to determine the relative importance of each of the alternatives with respect to each attribute. All these four matrices were

used to compute the overall priority weights for each cell in the framework as shown in Table 4 and Table 5 in the next section.

We note that the AHP technique was applied to the ERP customization framework while the implementation of ERP was progressing in our case study company. We acknowledge that, if applied to other settings and projects, the results will vary from one ERP project to another as the input from the ERP team varies. Once the inputs were collected, all the four 3 x 3 AHP matrices – Matrix A, Matrix B, Matrix C and Matrix D, were evaluated using the six steps of the AHP technique to find the priority values of each attribute.

The application of AHP to the customization framework yields three sets of results. They are: (a) Priority weights of each of the major attributes namely the application requirements, the process requirements and the design requirements from the viewpoint of customization; (b) Priority weights of the sub-attributes namely no change, incremental change and radical change attached to all the major attributes (application, process, design); (c) Overall priority weights for each cell in the framework computed using the results obtained in (a) and (b). Table 4 shows the overall priority weights for each cell in the framework. How these sets of results look is illustrated in the next section (see Tables 4 and 5) where we describe the findings of applying AHP to our case study data.

Findings

The outcome of the application of the AHP to the framework is the identification of nine feasible customization options available to the top management and the ERP implementation team of the implementing enterprise, as shown in Table 4. Here, the attribute with the higher priority value means that it is strongly recommended and the attribute with a low priority value means that it is the least preferred. The intermediate values give the various other options available for customization.

Major Attributes	Sub-Attributes	Customization Options	Overall Priority Value	Priority / Rank
Application	No Change (NC)	**ANC**	0.3921	1

Requirements (AR)	Incremental Change (IC)	**AIC**	0.1881	2
	Radical Change (RC)	**ARC**	0.0849	4
Process Requirements (PR)	No Change (NC)	**PNC**	0.1443	3
	Incremental Change (IC)	**PIC**	0.0617	6
	Radical Change (RC)	**PRC**	0.0251	8
Design Requirements (DR)	No Change (NC)	**DNC**	0.0662	5
	Incremental Change (IC)	**DIC**	0.0284	7
	Radical Change (RC)	**DRC**	0.0093	9

Table 4 Prioritization of ERP customization choices

Table 5 shows the overall priority values for the different attributes in the ERP customization framework obtained using AHP. In this table, No Change (NC), Incremental Change (IC) and Radical Change (RC) under the column 'Sub-Attributes' refers to the magnitude of changes recommended by the respondents of our case study for the major attributes: AR, PR and DR. Here, the 'NC' stands for no changes to be made, the 'IC' indicates the changes to be made in iterations and the 'RC' refers to a situation where a complete radical redefining of requirements is desired. It should be noted that the pairwise comparison in a judgment matrix in the AHP technique is accepted as satisfactory if the corresponding consistency ratio (CR) is less than 0.1 (Saaty, 1980).

The calculation of the CR coefficient consists of the following steps. At first, estimation of the consistency index (CI) is done. This requires adding the columns in the judgment matrix and multiplying the resulting vector by the vector of priorities (i.e., the approximated eigenvector) obtained earlier. This gives an approximation of the maximum eigenvalue, denoted by $L_{(Max)}$. Now, the CI value is estimated by means of a formula, namely: $CI = (L_{(Max)} - n)/(n - 1)$. Here, 'n' refers to the number of rows in the judgment matrix. Now, the consistency ratio 'CR' is calculated by dividing the CI value by the Random Consistency Index (RCI). For a given value of 'n', the RCI value can be found in a table defined by Saaty (Saaty, 1980) as part of the AHP technique.

CR is meant to measure how consistent the judgments have been relative to large samples of purely random judgments. If the CR is much in excess of 0.1 then

the judgments are unreliable since they are too close to randomness and the entire exercise of the data collected for AHP matrices is baseless or must be repeated (Saaty, 1980). If CR is less than or equals zero, then this means that the judgments are perfectly consistent. The consistency ratio for all the matrices (shown in Figure 2) in this study was less than 0.1 and hence the decision maker's pairwise comparison matrices were acceptable.

Attributes	NC	IC	RC
AR	**ANC** [1] (0.369)	**AIC** [2] (0.164)	**ARC** [6] (0.072)
PR	**PNC** [3] (0.160)	**PIC** [4] (0.079)	**PRC** [8] (0.029)
DR	**DNC** [5] (0.073)	**DIC** [7] (0.033)	**DRC** [9] (0.011)

Table 5 Customization choices for ERP: ranks and priority values

In Table 5, the value in the square bracket and the closed brackets in each cell represent the rank and priority value of the respective customization option. Furthermore, in Figure 3, the X-axis represents the various customization options and the Y-axis represents the priority value obtained using the AHP. We find that nine options are available, out of which the cell "ANC" is the most preferred and recommended. The least preferred cell is "DRC". We find that "AIC" and "PNC" are equally weighted. Hence if the customization becomes fundamental, the vendor can choose to customize the application requirements rather than touching upon the other functionality of the ERP system. In the views of our case study practitioners, ERP vendors should remember that the business processes have several touch-points, several of which cannot have access to the ERP system.

From Table 4 and Table 5, we find that less customization is most ideal when compared to incremental changes and radical changes that can be done to the application, process and design requirements of an ERP package. The cell "DRC" carries the least value. This substantiate the finding that utterly reengineering the

business processes of an organization and redesigning the ERP software accordingly would appreciably influence future competitiveness and performance of a company.

Next, Figure 3 shows the preferences of the practitioners for the different ERP customization options available to them. Figure 3 indicates that the strong suggestion from the practitioners is to accept the ERP as such, without any customization. It is also observed that radical redesign of the business processes and the ERP system has been considered as the last option during the AHP analysis. This could be because of the fact already noted in the previous studies (Luo and Strong, 2004; Parthasarathy and Anbazhagan, 2007; Rotherberger and Srite, 2009) that such a radical redesign of business processes and the ERP system would ultimately weaken the ERP. We note that the results on Figure 3 depend on the degree of changes the ERP team and the top management propose to make in their ERP system and the business process. Also, one might assume that choosing the right customization option not only depends on the degree of amendments but also on the technical and domain knowledge of the ERP consultants.

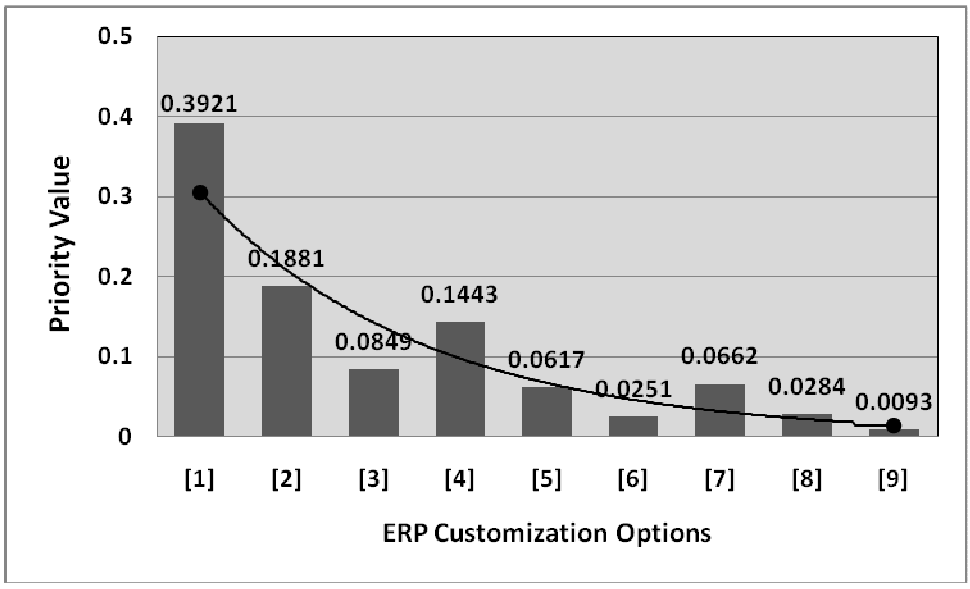

Figure 3 Different customization choices for ERP

We observe in Figure 3 that the ERP team has unanimously given a low priority value to design customization. This is not surprising, as customizing design requirements must ensure that the changes made to one segment of the design in a

module do not affect the other. In the experience of our practitioners, the ERP implementation team should be careful as the customization should not derail the standards of the ERP package, nor should it drive the organization to move too much away from these standards.

DISCUSSION

This section reflects on our experiences in terms of what we learned in the case study about the possible limitations of the proposed approach.

The purpose of the proposed ERP customization framework is to help with the evaluation of ERP customization options. We have demonstrated that it can serve as an approach for choosing customization options based on an organization's technical and business process requirements and capabilities. It suggests that the preferences for ERP customization should involve: 1) understanding the different attributes of ERP system customization and business process customization 2) analyzing the possibilities to execute the customization in iteration mode and 3) selecting a feasible cell (in Table 2) that matches customization options with the customer's requirements.

Given the customer's requirements, the framework can help the ERP team to assess the possibilities of customizing the ERP, keeping the business processes untouched, and vice versa. To carry out such an assessment procedure, the roles of practitioners involved in ERP are inevitable. In many companies, ERP system implementation is viewed as a series of implementation projects, thus the framework can be used to plan these projects by anticipating and facilitating the growth of technical and process change capabilities. With this dynamic view, we can envision difficult customization and implementation projects becoming feasible over time as capabilities build during prior implementation projects.

Furthermore, we evaluated the possible limitations (Yin, 2008) of this research. While the proposal for a customization framework was motivated by needs of ERP-adopting organizations, we designed it based on fundamental software engineering and requirements engineering principles described in the literature and on our own experience. The case study was our way to demonstrate the applicability of

our proposed framework complemented with the AHP technique. However, our case study is in no way a complete validation of the framework; it only illustrates its applicability in one organization. Also, we are conscious about the fact that decisions on customization do not happen in isolation from other important factors in an ERP project (Dey et al., 2010; Francoise et al., 2009).

Factors related to other integration initiatives, business process management (Bucher and winter, 2009), and business process re-engineering efforts usually accompany an ERP project. Hence customization becomes only one of the many factors that must be taken into account when implementing an ERP system. For this reason, we consider our framework be only one of the possible means that a company might consider using in a project. We think the framework could be employed jointly with other frameworks that an organization has already in place for ERP implementation.

The proposed ERP customization framework has to be applied to different organizational contexts, such as small and mid-sized companies and large organizations, so as to refine the various attributes of the framework. We have focused on assessing ERP as a generic software solution but the framework could also analyze particular packages, e.g. large-scale solutions offered by SAP or scaled-down solutions aimed at the mid-sized market. The framework can also be evaluated by inviting each adopting organization to provide data by specific business area, for example healthcare or financial services.

Furthermore, our case study happened in a mid-sized client organization in India. Clearly, we cannot claim generalizability of the results to all other mid-sized organizations involved in ERP implementation. However, following Seddon and Schepers (2012), we could expect that one might observe similar results in cases of ERP-adopting organizations that are similar to our case study organization. As these authors suggest, “if the forces within an organization that drove observed behavior are likely to exist in other organizations, it is likely that those other organizations, too, will exhibit similar behavior”. For example, we expect to have similar observations in mid-sized companies in the manufacturing sectors that face similar challenges as our

case study organization and are looking for a complete business solution to improve their customer satisfaction index.

IMPLICATIONS FOR PRACTITIONERS AND RESEARCHERS

Our work has some implications for practitioners and researchers. To practitioners, we provided a simple and straightforward approach to considering customization and to prioritize customization choices. Business process management specialists might consider it particularly useful in projects in which clients have relatively little technical knowledge of ERP customization and are pressed for time to make customization decisions. Moreover, the proposed framework allows ERP team members to explore many implementation possibilities classified in nine groups of preferences. These preferences depend on how much to change the business process and how much to change the ERP system – rather than simply following the "traditional wisdom" of fitting processes to the system. The consequence of using the framework is the possibility to visualize ERP implementation as a portfolio of projects. Different customization scenarios can be treated as projects within a portfolio and each project may require different levels of effort, resources, and expertise of consultants. The expectations of the implementing organization may also vary from one to another. Thus, they should be managed in their own way.

To researchers, our study opens up a few lines for further research: first and most importantly, as we discussed earlier, we assume our framework would be applicable in other organizations that are similar to our case study organization. To collect evidence and substantiate this claim, we will need further case studies. This will provide the aspects in which it may need further refinement, extension or improvement. This represents a line for future research.

Second, it would be interesting to investigate the use of the framework in large projects; we expect there will be aspects to be changed. For example, more mature companies usually think of more customization (Bucher and Winter, 2009). We therefore expect that our framework might need an additional dimension to acknowledge the variety and multitude of types of customization relevant for large

and very large organizations and projects. To discover this, more research is needed in large project contexts.

Third, in using the AHP technique, there is a tacit assumption that stakeholders will be able to decide on preferences and will have the time to consider their preferences in sufficient depth. However, business dynamics and pressure within companies to get more work done with fewer human resources might render this assumption unrealistic in all cases. What cost-effective approaches could be used to elicit preferences and how to incorporate them into our framework, forms a line for future research.

Last, as the number of stakeholders and/or requirements and customization options to be considered grows, so does the number of comparisons. We think therefore that it is worthwhile extending existing tools for customization management with functionality to cope with large numbers of stakeholders and requirements.

CONCLUSIONS

This paper presented a framework for ERP customization that was built on a software engineering and requirements engineering foundation. Being grounded in these disciplines is a unique feature of our framework compared to other previously developed frameworks that focus more on theoretical perspectives from social and organizational sciences (e.g. those presented in Table 1). While there have been previous studies that examined the customization process during the ERP implementation, most of the previous work focused on managerial aspects of customization and they are not grounded on the customer's requirements. In this sense, our study adds to the body of knowledge in the field of ERP customization evaluation by examining it from the customer requirements perspective.

We have devised an approach to identify a set of prioritized customization choices from a framework using the AHP technique for the ERP team. The framework offers the ERP team members a way of thinking about the implementation choices to be made at three level of requirements namely the application, the process and the design. The applicability of the framework and its use with the AHP technique were demonstrated by using a case study in a mid-sized company in India

involved in ERP implementation. Data were collected from the ERP team members from this mid-sized company. The nine customization options in the ERP customization framework based on the customers' requirements were prioritized by applying the AHP technique.

Our findings suggest that the implementing organization should consider the option of accepting the ERP as such from the vendor, if they would like to reap the benefits of ERP completely. The next option suggested by the practitioners is to make some incremental changes in the application requirements to make the ERP fit into the organization. The least preferred option is to perform a radical redesign of the ERP system and the business processes. This is risk-prone and involves a complete business process re-engineering of the business processes of the organization and the complete re-design of the corresponding ERP system.

We consider our study and its results a first step only and we are conscious of the value of replication studies that would help to accumulate more evidence. Our immediate future research plans include carrying out follow-up studies in which our goal is to increase the understanding of the customization framework and its applicability in various contexts. A future analysis study may compare the framework employed in this study with some selected frameworks noted in the literature, with reference to customization. For example, a new framework could be developed to address the customization process as well as its impact on other factors like project management, reengineering, or skill sets of the ERP team members.

A future research study could also compare the performance of the ERP system using our customization framework with those not using the framework in a controlled laboratory study. Once further understanding of the framework in use is developed, the framework should be tested with large dataset involving more practitioners in a similar way in multiple organizations. This would help us to validate the framework more fully than was done in this study.

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