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Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard

Ufuk Cebeci*

Department of Industrial Engineering, Istanbul Technical University, Macka, Istanbul 34367, Turkey

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ABSTRACT

An enterprise resource planning system (ERP) is the information backbone of a company that integrates and automates all business operations. It is a critical issue to select the suitable ERP system which meets all the business strategies and the goals of the company. This study presents an approach to select a suitable ERP system for textile industry. Textile companies have some difficulties to implement ERP systems such as variant structure of products, production variety and unqualified human resources. At first, the vision and the strategies of the organization are checked by using balanced scorecard. According to the company's vision, strategies and KPIs, we can prepare a request for proposal. Then ERP packages that do not meet the requirements of the company are eliminated. After strategic management phase, the proposed methodology gives advice before ERP selection. The criteria were determined and then compared according to their importance. The rest ERP system solutions were selected to evaluate. An external evaluation team consisting of ERP consultants was assigned to select one of these solutions according to the predetermined criteria. In this study, the fuzzy analytic hierarchy process, a fuzzy extension of the multi-criteria decision-making technique AHP, was used to compare these ERP system solutions. The methodology was applied for a textile manufacturing company.

1. Introduction

ERP systems are becoming more necessary for almost every firm to improve the competitiveness. According to the success of the implementation of ERP system; companies can obtain a competitive advantage in the global market rapidly. Over the past decade, many ERP projects have resulted in substantial tangible and intangible improvements in a variety of areas for the organizations (Davenport, 2000; Umble, Haft, & Umble, 2003; Yusuf, Gunasekaranb, & Abthorpe, 2004). However, there are a number of examples where organizations were not successful in reaping the potential benefits that motivated them to make large investments in ERP implementations (Davenport, 2000; Umble et al., 2003).

Implementations of ERP systems are one of the most difficult investment projects because of the complexity, high cost and adaptation risks. Companies have spent billions of dollars and used numerous amounts of man-hours for installing elaborate ERP software systems (Yusuf et al., 2004). A successful ERP project involves selecting an ERP software system and co-operative vendor, implementing this system, managing business processes change and examining the practicality of the system (Wei & Wang, 2004). Karsak and Özogul (2009) presented a novel decision framework for ERP software selection, employing quality function deployment, fuzzy linear regression and zero–one goal programming. Teltumbde (2000) proposed a methodology based on the nominal group technique and the AHP for evaluating ERP systems. Chang et al. (2008) proposed a neural network evaluation model for ERP performance from SCM perspective. The survey data was gathered from a transnational textile firm in Taiwan (Table 4).

Determining the best ERP software that fits with the organizational necessity and criteria, is the first step of tedious implementation process. Hence, selecting a suitable ERP system is an extremely difficult and critical decision for managers. An unsuitable selection can significantly affect not only the success of the implementation but also performance of the company. However, many companies install their ERP systems hurriedly without fully understanding the implications for their business or the need for compatibility with overall organizational goals and strategies (Hicks & Stecke, 1995). The result of this hasty approach is failed projects or weak systems whose logic conflicts with organizational goals. This paper aims:

- to manage the early stages of ERP selection according to the vision and strategies by using balanced scorecard and
- to provide an analytical tool to select the most suitable ERP software for textile industry.

* Tel.: +90 212 2931300; fax: +90 212 2407260.
E-mail addresses: cebeciu@itu.edu.tr, ufuk_cebeci@yahoo.com

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Kumar, Maheshwari, and Kumar (2003) investigated the key considerations and successful strategies in ERP implementation projects. Byun (2001) explored the use of AHP for deciding on car purchase. Cebeci and Ruan (2007) investigated some quality consultants using fuzzy AHP. Wei, Chien, and Wang (2005) proposed a comprehensive framework for selecting a suitable ERP system based on an AHP-based decision analysis process. The AHP is one of the extensively used multi-criteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. Perry, Sohal, and Rumpf (1999) described quick response supply chain alliances in the Australian textiles, clothing and footwear industry. Calisir, Kulak, and Dogan (2005) explored the influence of various factors on textile companies' satisfaction with ISO 9000. Chand, Hachey, Hunton, Owhoso, and Vasudevan (2005) provided a balanced scorecard (BSC)-based framework for valuing the strategic contributions of an ERP system. This paper illustrates that an ERP system does indeed impacts the business objectives of the firm. Eilat, Golany, and Shtub (2008) presented a multi-criteria approach for evaluating R&D projects by using the balanced scorecard and data envelopment analysis (DEA).

The organization of this paper is as follows. First textile and clothing industry and the case of Turkey are analyzed. Then the balanced scorecard method is explained and the proposed methodology is introduced. Fuzzy sets and fuzzy numbers are introduced because our comparison method, fuzzy AHP, includes fuzzy numbers and their fuzzy algebraic operations. Then, a comparison among ERP vendors is made by using fuzzy AHP for a textile firm as a real life case study.

2. Textile and clothing industry and the case of Turkey

The industrialization efforts of the sixties and seventies gave birth to the modern textile industry in Turkey. At the beginning, this sector operated as small workshops. In time the sector showed rapid development and during the seventies began exporting. Currently it is one of the most important sectors in the Turkish economy in terms of GDP, employment and exports. Turkey is one of the main actors in the world textile and clothing industry. The Turkish clothing industry is the fourth largest supplier in the world, and the second largest supplier in the EU. The Turkish textile industry is in the world's top ten exporters [www.yarnsandfibers.com].

As a quality cotton-producing country, Turkey has an integrated and diversified production in all sub-sectors of the textile industry, produces and exports all types of yarn, fabric, clothing, household textiles and other ready-made products.

Today, the Turkish textile and clothing industry is aware of the trend in international markets towards increasing demand for healthier and more environmentally friendly products and tries to adapt it to these developments within legal and technical regulations.

Some major markets for Turkish clothing exports are Germany, the USA, the Russian Federation, the UK, France, the Netherlands and Poland [www.igeme.org.tr, 2005].

Textile industry means from cotton to textile, sewing. The textile industry has a great importance for Turkish export goods. The industry is facing a serious competition because of cheap workforce in some Far East countries, Pakistan and India. The textile companies in Turkey used to supply clothes that are ready to be used in sewing production, but nowadays most of them should first buy cotton (raw material), then they should send for thread production, after the clothes prepared, they are sent for dyeing; at last the clothes for sewing are ready. Although processes are more complicated, the costs are cheaper in this way. Even some big firms prefer the outsourcing of sewing, especially after the cutting the clothes. As a result, the supply chain management concept becomes more important. To select and implement a suitable ERP system are vital for the textile industry.

3. The balanced scorecard

Many companies have mission statements and visions, which are translated into business strategies. However, often these strategies never fully implemented in the organization. The balanced scorecard is a tool that can help translate visions and strategies into an integrated set of performance and action. Kaplan and Norton (1992) introduced. The balanced scorecard concept as a strategic performance management system. Kaplan and Norton (1996) define balanced scorecard concept as follows:

> "The balanced scorecard retains traditional financial measures. But financial measures tell the story of past events, an adequate story for industrial age companies for which investments in long-term capabilities and customer relationships were not critical for success. These financial measures are inadequate, however, for guiding and evaluating the journey that information age companies must make to create future value through investment in customers, suppliers, employees, processes, technology, and innovation."

A strategic planning study such as balanced scorecard is very useful from vision to action. Kaplan and Norton (1996) state that "the balanced scorecard translates an organization's mission, vision and strategy into a comprehensive set of performance measures and provides the framework for strategic measurement and management". The balanced scorecard concept measures organizational performance across four balanced perspectives: financial perspective, customer perspective, internal business perspective and learning and growth perspective. They state that balanced scorecard tells you the knowledge, skills and systems that your employees will need (learning and growth perspective) to innovate and build the right strategic capabilities and efficiencies (internal processes perspective) that deliver specific value to the market (customer perspective) which will eventually lead to higher shareholder value (financial perspective) (Fig. 1).

Financial perspective: financial objectives serve as the focus for the objectives and measures of the other three perspectives. Every measure should be part of a cause-and-effect relationship culminating in long-term, sustainable financial performance. Customer perspective: financial success is closely linked to customer satisfaction. Satisfied customers mean repeat business, referrals and new business, and thereby contribute to the financial results of the company. Internal operations perspective: customer satisfaction is directly achieved through the operational activities of the company. The objectives and measures for this perspective thus enable a company to focus on maintaining and improving the performance of processes that deliver the established objectives that are key to satisfying customers, which in turn satisfy shareholders. Learning and growth perspective: the ability, flexibility and motivation of staff support all of the financial results, customer satisfaction and operational activities measured in the other three quadrants of the balanced scorecard.

The balanced scorecard shows how the overall strategic objectives are translated into the performance drivers that the company has identified as critical success factors. The performance drivers are translated into more tangible measures that allow the company to quantify the performance drivers. Measurements should continue over time allowing comparisons.

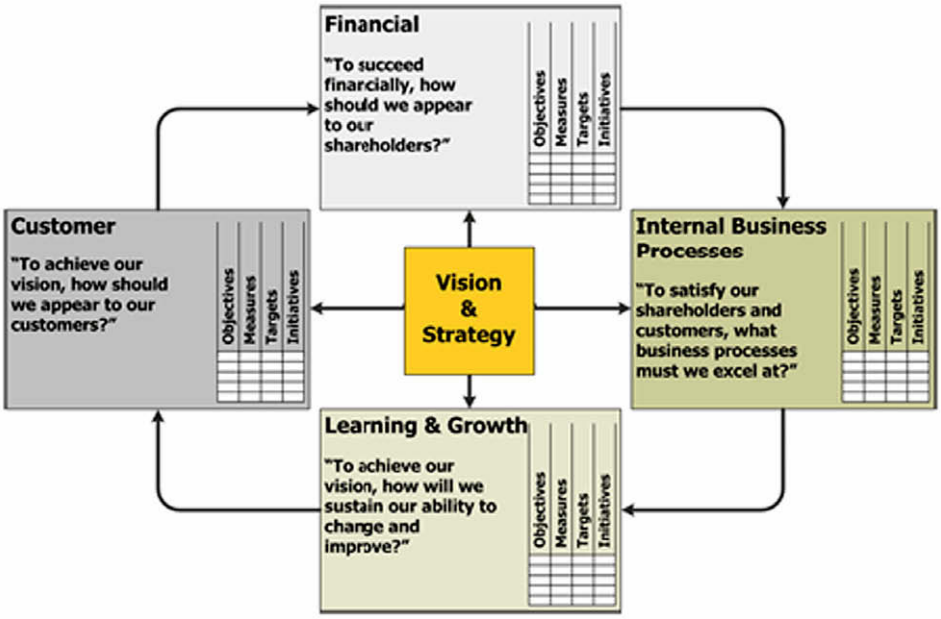

Fig. 1. The structure of balanced scorecard developed by Kaplan and Norton (1996).

4. The proposed methodology

The proposed methodology aims to manage the stages of ERP selection and to provide an analytical tool to select the most suitable ERP software for textile industry. Figs. 3 and 4 illustrate the conceptual framework of the proposed methodology as developed by the author.

4.1. The balanced scorecard for strategic management phase

It is very important to match the ERP package objectives with the business objectives. Therefore strategic management phase should be completed. In textile industry, the determination of a vision and strategies is very important. Since most of the textile companies (especially single and medium-size enterprises) in Turkey have no clear vision statement and long-range planning, the changes in the global market affect them too much. Therefore the strategies of the organization should be determined clearly. After the top management commitment, these statements should be communicated and understood within the organization. In order for a successful balanced scorecard system to be established there are some predecessor processes such as deployment of vision, SWOT analysis (strengths, weaknesses, opportunities, and threats). It is very useful to determine strategies after a SWOT analysis.

BSC helps to define key objectives, benefits and expectations before you start. Key performance indicators (KPIs) are determined, thus the expectations for ERP will be clear. After determining the vision and the strategies, the ERP project team may focus the ERP implementation by considering KPIs and some unsuitable ERP systems according to the vision, may be disqualified.

Key performance indicators are also very useful to prepare a satisfactory request for proposal (RFP). An RFP is a document containing a detailed list of technology and business requirements for a given project. This document is typically sent to a targeted group of vendors to solicit their proposals to work on the project. RFPs are valuable tools to ensure that vendors deliver the exact solutions that you need. An RFP allows vendors to clearly understand customer needs so they can provide you with more accurate estimates of costs and time frames. There is no study focusing request for proposals in the literature. This study focuses RFPs by using Balanced Scorecard concept.

4.2. The other facilities for strategic management phase

A project team should be constituted and a team leader from top management should be assigned as management representative. The support and involvement of top management influence all stages of ERP selection and implementation. Some responsibilities of a project team are:

- to integrate the points between departments/processes,
- to determine and coordinate necessary trainings such as on-job training, seminars,
- to publish and revise the project plan,
- interdepartmental communication.

When comparing to other sectors, human resources in textile sector are weak in general. If human resources are weak in a company for ERP usage, then, the key users in the firm should be trained and/or new employees should be hired.

After obtaining enough data about the ERP software packages and vendors, unsuitable ones can be disqualified. Some rules to eliminate them are:

- Variant type production support.
- Successful references in the textile sector.
- Balance of the budget for ERP and total ERP implementation cost.
- The requirements of ERP and current information system infrastructure.

If ERP package has no variant type production support, it is very difficult to enter data or obtain reports efficiently. The variant concept used in textile is explained in Fig. 2. The total quantity of the customer order is 340, but the total quantity of "small size" is 60, the total quantity of "black color" is 90 and the quantity of "small size" and "black color" jackets is 15. The dimensions of some accessories such as zips may change according to the size of product and the colors of accessories will change for different

Product Description: Jacket Model Number 315 The total quantity ordered : 340

COLOR / SIZE	*SMALL*	*MEDIUM*	*LARGE*	*EXTRA LARGE*	*TOTAL*
BLACK	15	30	25	20	90
BROWN	25	45	35	30	135
BLUE	20	35	35	25	115
TOTAL	60	110	95	75	340

Fig. 2. An example of variant concept used in textile.

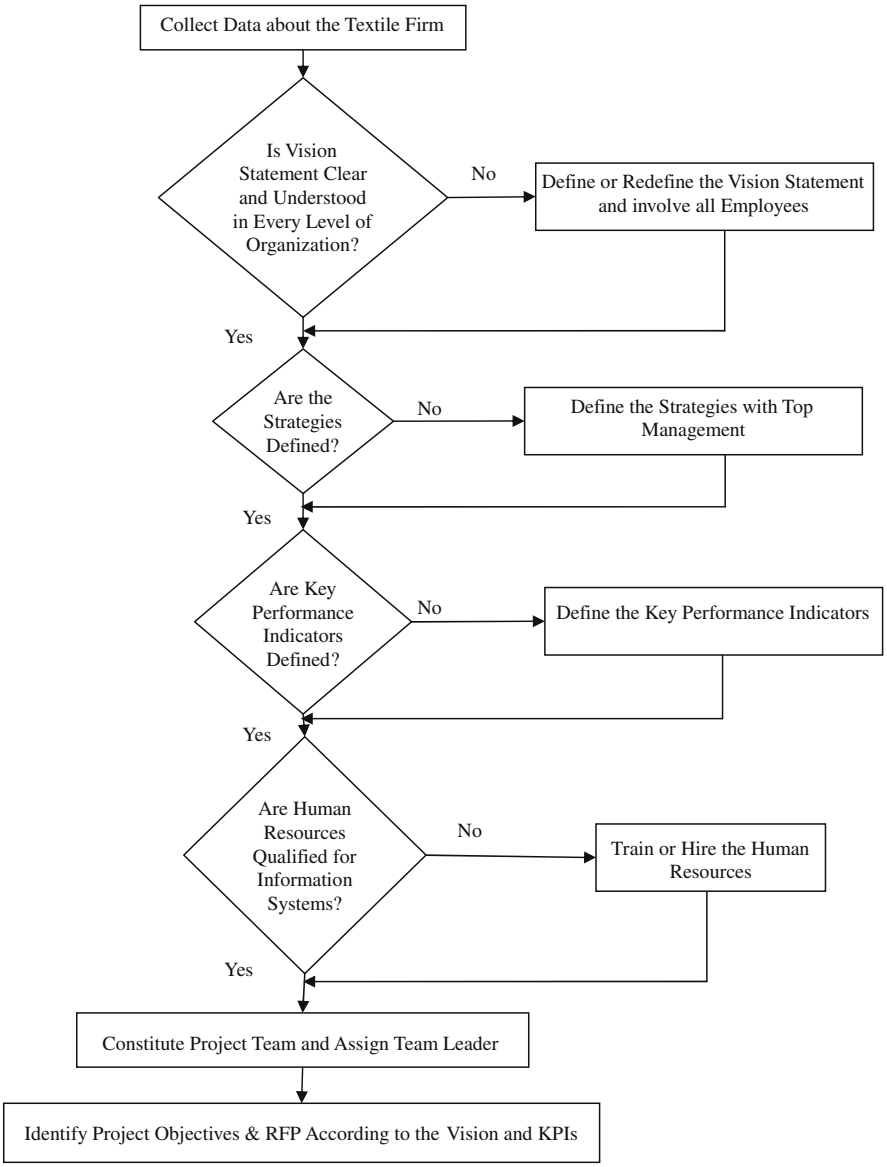

Fig. 3. ERP system selection flow chart – strategic management phase.

colored products. It is very difficult to form a bill of material, materials requirement plan, purchasing orders, production plan, etc., by using a classical ERP package. Even the most of the firms that are close to repetitive production cannot use the advantages of this type of production, because most of the firms in textile industry produce fashion goods with changing properties such as color, pocket type, button instead of zip, for every year and season.

Having variant type production support may not be sufficient; therefore, successful references in textile sector are another important point to be considered. If it is possible, visiting successful references is strongly recommended.

- If the difference between total ERP implementation cost and considered budget for ERP project is unacceptable, then, the candidate ERP package is eliminated. Another elimination rule is the difference between the requirements of ERP and current information system infrastructure.

An ERP package which does not support variant type production may be suitable if it is used with "add-on" software supporting variant type production.

Then, the fuzzy AHP structure is created and applied. After the analysis, the evaluation process can be improved if required, or the final decision is made.

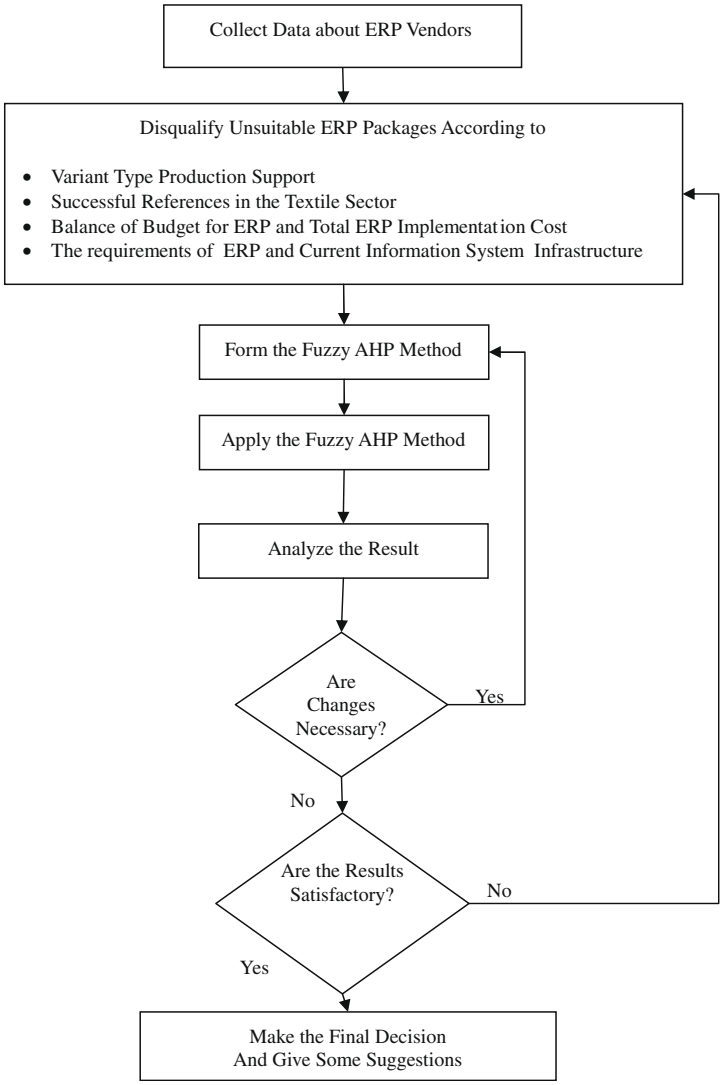

Fig. 4. ERP system selection flow chart – decision phase.

The methodology also gives some suggestions about successful ERP implementation:

- Define a realistic project plan. If enough time is not allotted, ongoing changes may occur.
- You can hire a consultant experienced about textile and ERP implementation and select the one with good communication skills.
- Check the progress of the project frequently. People may change their mind for various applications, if they are not critical ones, you can evaluate later and prevent project delay.
- Inform people who will be affected by the outcome, about the gaining of new system, and then you can involve people.
- Match the ERP software with your business culture and textile sector (if necessary).

Another important subject is the minimal customization of ERP package. There will be upgrade problems, if the source code of software is changed too much.

5. Fuzzy sets and fuzzy numbers

To deal with vagueness of human thought, Zadeh (1965) first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. Zimmermann (1994) gives the algebraic operations with triangular fuzzy numbers (TFNs). Many ranking methods for fuzzy numbers have been developed in the literature. They do not necessarily give the same rank. The algebraic operations with fuzzy numbers can be found in Kahraman (2001) and Kahraman, Ruan, and Tolga (2002).

6. A real life case study

In this study, some textile companies are visited and studied their production, sales, purchasing and other processes carefully. The companies producing different type of textile products are selected .The companies visited have also different size such as employee numbers, revenue. The firms with ISO 9001 or trying to get certification are selected to understand their critical processes, to obtain documentation such as procedures, work instructions and

job descriptions, statistical data. The textile firms visited are Liteks (Alez fabric, surgery apron fabric, canvas fabric, ready made clothes, outdoor, technical textile and home textile) – www.liteks.com, Fer-Ko textile work wear (www.ferkotex.com), Akyuz textile, producing ready-to-wear products (www.akyuztekstil.com.tr) Fab textile, producing ready-to-wear products (www.fabteks.com.tr), Erim (knitted dyeing, fabric dyeing and printing), Ismont work wear (www.ismont.com.tr), Baymen textile, producing ready-to-wear products for young people (www.doramafitextile.com).

Baymen was chosen to apply this study, the reasons to select this company are:

- the present software was insufficient for some modules,
- inventory costs are very high for fast fashion companies,
- competition is increasing in the industry and the prices are decreasing,
- the system is becoming more complex, since Baymen's new stores are being opened in Turkey and foreign countries and the outsourced operations are increasing,
- the top management supports this project,
- the present production of the company is related with all the processes of textile industry so that the methodology can be tested in a suitable way.

6.1. Strategic management phase

Baymen has a clear vision statement. The vision was determined by using a balanced scorecard project. A management consultant managed the balanced scorecard project and the top management supported this strategic management application. The vision, mission, strategies, perspectives and key performance indicators are determined at the meetings participating managers from all departments including top management.

Baymen's shared vision statement is "to become a worldwide company with different product designs for young people".

After a SWOT analysis (strengths, weaknesses, opportunities, and threats), strategies are determined:

- To increase the image of the trademark in the present markets and penetrate new markets.
- To optimize product variety to compete.
- To decrease manufacturing and purchasing costs.
- To sustain the loyalty of the customers and the personnel.

The balanced scorecard is based on four key perspectives:

Financial perspective: "How will we look to our stake holders?"
Customer perspective: "How must we look to our customers?"
Internal processes perspective: "What internal processes must be excelling at?"
Learning and growth perspective: "How can the organization learn and improve?"

Key performance indicators determined are shown in Table 1 for four perspectives.

After the analysis it is decided that the human resources are qualified for information systems.

Baymen's strategy map is formed to determine the cause-and-effect relations between goals.

The determined strategy map is shown in Fig. 5.

In the strategy map, the directions of the arrows show which goals have an effect on which goals. For example, customer satisfaction-C1 has an effect on customer loyalty-C2 and market share-F3. If customer satisfaction increases then customer loyalty and market share also increase.

Table 1
Key performance indicators for Baymen.

Perspective	KPI	Frequency
Finance	Profitability	Yearly
	Revenue growth	Yearly
	Export growth	Yearly
Customer	Customer satisfaction survey	Yearly
	Customer complaints	Quarterly
	In-time delivery	Quarterly
	Customer loyalty	Half-yearly
	Image of the trademark	Half-yearly
	Ppm (defective parts per million)	Quarterly
Internal processes	Capacity utility	Quarterly
	Lead time	Quarterly
	Profitability per employee	Quarterly
	Number of value-added suppliers integrated with ERP	Quarterly
	Number of successful designs	Half-yearly
	Time to market for designs	Quarterly
	Inventory level	Quarterly
Learning and growth	Employee turnover	Yearly
	Employee suggestions implemented	Quarterly
	Employee satisfaction	Yearly
	Efficiency of employees qualified for key jobs including information systems	Quarterly
	Training hours	Quarterly

6.2. Preparing request for proposal

Almost every report monitoring KPIs should be obtained by using ERP so that the company can achieve the strategies and the vision. The KPIs of Baymen; profitability, revenue growth, export growth, customer complaints, in-time delivery, customer loyalty, Ppm (defective parts per million), capacity utility, lead time, profitability per employee, number of value-added suppliers integrated with ERP, time to market for designs, inventory level, employee turnover, efficiency of employees qualified for key jobs will be controlled by means of ERP directly. These KPIs are very important to prepare a request for proposal.

Some highlights of RFP for Baymen are as follows:

- *Number of value-added suppliers integrated with ERP:* Electronic data interchange property is necessary to control and manage suppliers and outsourced manufacturing items. If the number of suppliers increases (because the most of the manufacturing is outsourced), supplier relationship management module is required to control supplier contracts and agreements, rating of suppliers, requisitions and quotations, procurement reporting and online reporting, management of purchase orders.
- *Customer loyalty: Some* data mining features are necessary to observe customer behavior especially end-users'.
- *Lead time: Some* drill-down reporting tools are necessary to analyze bottleneck operations inside and outside company. "Make or buy decision" support data is necessary for production of some items. Even the same items may be produced in the company and outside at the same time because of time limits.
- *Efficiency of employees qualified for key jobs: It* is very difficult to monitor the efficiencies of employees for textile companies such as Baymen, because production volumes are low, product variety is high and products have different bill of materials, and operations. The ERP to be selected should include features to normalize different products with various manufacturing difficulties.
- *Revenue growth, export growth and profitability: Multiple* cost associations for each item and location. What-if scenarios module is necessary to measure the affects of changing costs.

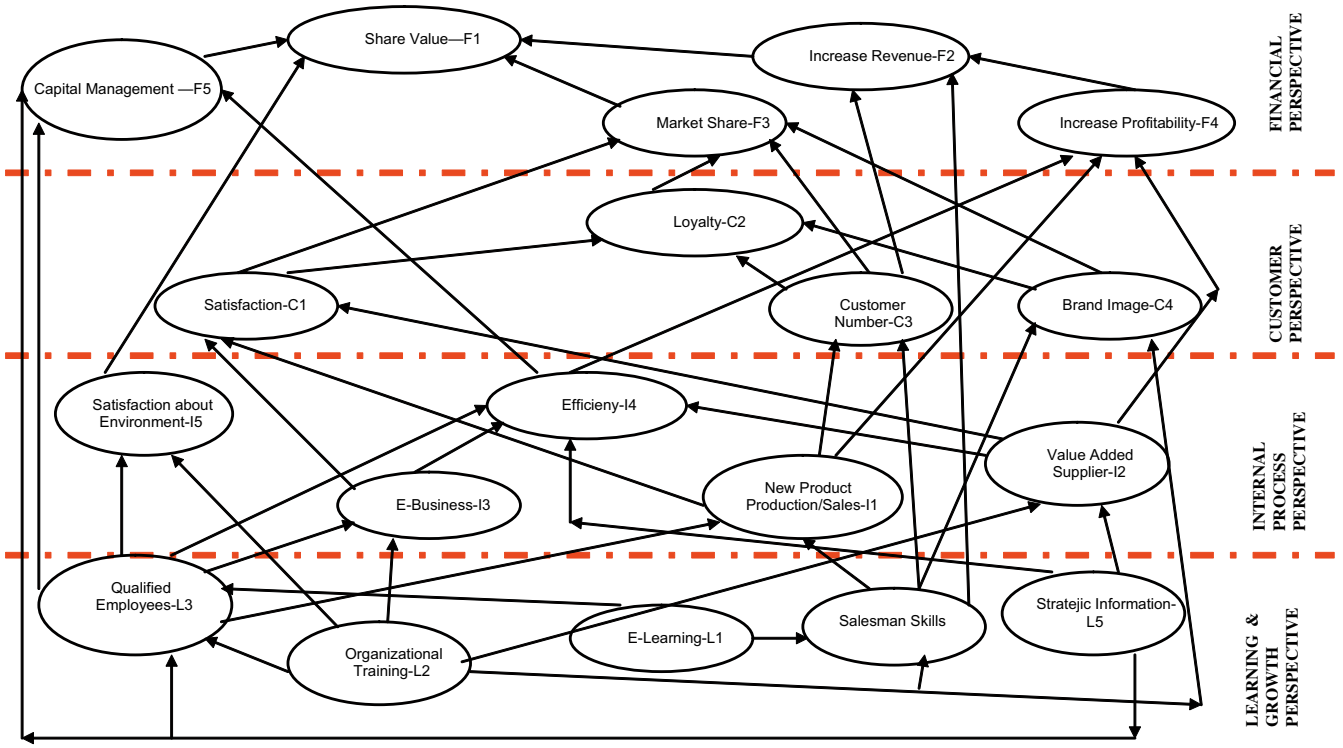

Fig. 5. Baymen's strategy map.

– *Time to market for designs: Project* management module for new designs is required to monitor costs and work schedules on a project-by-project basis. It usually includes the following sub-modules: project control, project analyzer, project budgeting, project timekeeping, and project billings.
– *Inventory level: Solutions* for inventory management are used for the record-keeping of goods that are warehoused, and managing the movement of these goods to, from, and through warehouses. It is also important to monitor the returned unsuccessful designs inventory level.

Learning and growth related KPIs: human resources module should support the following functionality: recruitment management; personnel information and tracking; organizational structuring; job position and salary profile; career development, training and performance management; compensation management; budgeting and cost control; government compliance reporting; expenses management; union information; discipline actions and grievances tracking; and employment history/personnel reporting.

According to the Baymen's strategies and vision, we can notice that multi-lingual menus, different currencies, e-commerce and retailing applications, web user features and OLAP data warehouse for consolidation of data from multiple sources are required.

6.3. Decision phase

Five ERP packages that do not meet the requirements of the company are eliminated:

- 1 ERP package which does not support retailing.
- 1 ERP package which does not support variant type production.
- 1 ERP package of which total implementation cost is very high.
- 1 ERP package of which textile references are unsatisfactory.
- 1 ERP package which does not support multi-lingual menu.

The rest three ERP system solutions were selected to evaluate. One ERP software is added to candidate ERP packages with "add-on" software supporting variant type production.

An external evaluation team consisting of three ERP consultants was assigned to select one of these solutions according to the predetermined criteria.

The AHP model provides priority weights for the ERP packages, based on the ERP project team's preferences on multiple criteria. The alternative with the highest priority weight is then selected for the firm (Fig. 6).

The attributes were determined according to the vision and the strategies of the company, managers' opinions, literature and a questionnaire: the questionnaire was constructed based on an extensive review of the literature in the areas of ERP implementation. One manager from each enterprise who was a member of the project team for implementing ERP asked to rate the level of the

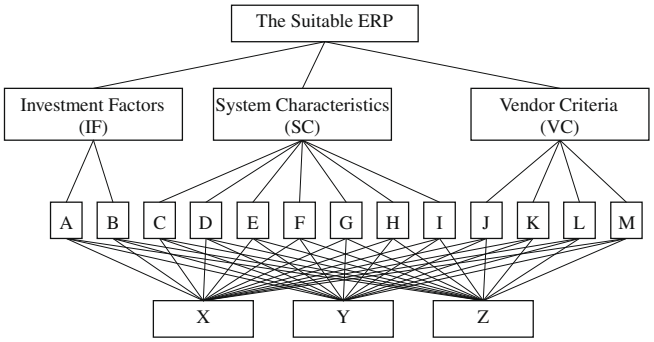

Fig. 6. The AHP model. A. Total cost, B. Implementation, C. Functionality, D. Ease in customizing the system (Flexibility), E. Systems reliability, F. User friendliness M. R&D capability, G. Better fit with company's business processes, H. Ability for upgrade in-house, I. Compatibility with other systems, J. After sales service (Consultancy services), K. Vendor reputation, L. Terms and period of guarantee.

Table 2
The questionnaire for the importance of main attributes with respect to the goal.

Each attribute with respect to the other		For the ERP vendors									
Question number	Attribute	Absolutely important (7,9,9)	Very strongly important (5,7,9)	Fairly important (3,5,7)	Weakly important (1,3,5)	Equally important (1,1,1)	Weakly important (1,3,5)	Fairly important (3,5,7)	Very strongly important (5,7,9)	Absolutely important (7,9,9)	Attribute
1	IF					✓					SC
2	IF						✓				VC
3	SC				✓						VC

importance of the criteria. Seventy-three companies gave their consent to participate in this study (Table 2).

Some questionnaires aiming at determining the degrees of preference by the help of the pairwise comparisons among the attributes are prepared. The questionnaires facilitate the answering of pairwise comparison questions. The external evaluation team compared the three ERP software and vendors with respect to each attributes. The meanings of the attributes were explained in detail to every one in project team so that every one would understand the same thing when they read the questionnaire. After assigning the weights to each attribute, the evaluation team compared all ERP alternatives: *X*, *Y* and *Z*. The matrix of paired comparisons for alternatives is given in Tables 5–19. Finally, adding the weights for ERP vendor alternatives multiplied by the weights of the corresponding criteria, a final score is obtained for each alternative. Table 20 shows the final scores for the ERP vendors and after applying the methodology, solution *Y* is selected.

Table 3
Pairwise comparisons of main attributes with respect to the goal.

	X	*Y*	*Z*
X	(1,1,1)	(1/7,1/5,1/3)	(1/5,1/3,1)
Y	(3,5,7)	(1,1,1)	(3,5,7)
Z	(1,3,5)	(1/7,1/5,1/3)	(1,1,1)

Table 4
Pairwise comparisons of attributes with respect to investment factors.

	A	B
A	(1,1,1)	(1,1,1)
B	(1,1,1)	(1,1,1)

Table 5
Pairwise comparisons of attributes with respect to system characteristics.

	C	D	E	F	G	H	I
C	(1,1,1)	(1,3,5)	(3,5,7)	(3,5,7)	(3,5,7)	(1,3,5)	(5,7,9)
D	(1/5,1/3,1)	(1,1,1)	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,1)	(1,3,5)
E	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,3,5)
F	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,3,5)
G	(1/7,1/5,1/3)	(1/5,1/3,1)	(1/5,1/3,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)
H	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(3,5,7)
I	(1/9,1/7,1/5)	(1/5,1/3,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1/7,1/5,1/3)	(1,1,1)

Table 6
Pairwise comparisons of attributes with respect to vendor criteria.

	J	K	L	M
J	(1,1,1)	(1,3,5)	(1,3,5)	(5,7,9)
K	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,1,1)
L	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,3,5)
M	(1/9,1/7,1/5)	(1,1,1)	(1/5,1/3,1)	(1,1,1)

Let $\tilde{p}_{ij}$ be a set of decision makers' preference of one attribute over another then; construct the pairwise comparison matrices such as

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{p}_{12} & \dots & \tilde{p}_{1n} \\ \tilde{p}_{21} & 1 & \dots & \tilde{p}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{p}_{n1} & \tilde{p}_{n2} & \dots & 1 \end{bmatrix}$$

where n is the number of the related elements at the level.

The fuzzy weights of each attribute of synthetic pairwise comparison matrix are obtained by the geometric mean method suggested by Buckley (1985).

The geometric mean of fuzzy comparison value of attribute i to each attribute can be found:

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{p}_{ij} \right)^{1/n}, \quad i = 1, 2, \dots, n \tag{1}$$

Table 7
Pairwise comparisons of alternatives with respect to attribute A.

	X	*Y*	*Z*
X	(1,1,1)	(1,3,5)	(1,3,5)
Y	(1/5,1/3,1)	(1,1,1)	(1,3,5)
Z	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)

Table 8
Pairwise comparisons of alternatives with respect to attribute B.

	X	*Y*	*Z*
X	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)
Y	(1,3,5)	(1,1,1)	(1,1,1)
Z	(1,3,5)	(1,1,1)	(1,1,1)

Table 9
Pairwise comparisons of alternatives with respect to attribute C.

	X	*Y*	*Z*
X	(1,1,1)	(1/7,1/5,1/3)	(1/5,1/3,1)
Y	(3,5,7)	(1,1,1)	(1,3,5)
Z	(1,3,5)	(1/5,1/3,1)	(1,1,1)

Table 10
Pairwise comparisons of alternatives with respect to attribute D.

	X	*Y*	*Z*
X	(1,1,1)	(1,3,5)	(3,5,7)
Y	(1/5,1/3,1)	(1,1,1)	(1,3,5)
Z	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)

Table 11
Pairwise comparisons of alternatives with respect to attribute E.

	X	Y	Z
X	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)
Y	(1,1,1)	(1,1,1)	(1/5,1/3,1)
Z	(3,5,7)	(1,3,5)	(1,1,1)

Table 12
Pairwise comparisons of alternatives with respect to attribute F.

	X	Y	Z
X	(1,1,1)	(1,3,5)	(3,5,7)
Y	(1/5,1/3,1)	(1,1,1)	(1,3,5)
Z	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)

Table 13
Pairwise comparisons of alternatives with respect to attribute G.

	X	Y	Z
X	(1,1,1)	(1/5,1/3,1)	(1,1,1)
Y	(1,3,5)	(1,1,1)	(1,3,5)
Z	(1,1,1)	(1/5,1/3,1)	(1,1,1)

Table 14
Pairwise comparisons of alternatives with respect to attribute H.

	X	Y	Z
X	(1,1,1)	(1,1,1)	(3,5,7)
Y	(1,1,1)	(1,1,1)	(1,3,5)
Z	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,1,1)

Table 15
Pairwise comparisons of alternatives with respect to attribute I.

	X	Y	Z
X	(1,1,1)	(1/5,1/3,1)	(1/7,1/5,1/3)
Y	(1,3,5)	(1,1,1)	(1/5,1/3,1)
Z	(3,5,7)	(1,3,5)	(1,1,1)

Table 16
Pairwise comparisons of alternatives with respect to attribute J.

	X	Y	Z
X	(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)
Y	(3,5,7)	(1,1,1)	(1/5,1/3,1)
Z	(3,5,7)	(1,3,5)	(1,1,1)

Table 17
Pairwise comparisons of alternatives with respect to attribute K.

	X	Y	Z
X	(1,1,1)	(1/7,1/5,1/3)	(1/5,1/3,1)
Y	(3,5,7)	(1,1,1)	(1,3,5)
Z	(1,3,5)	(1/5,1/3,1)	(1,1,1)

Table 18
Pairwise comparisons of alternatives with respect to attribute L.

	X	Y	Z
X	(1,1,1)	(3,5,7)	(1/5,1/3,1)
Y	(1/7,1/5,1/3)	(1,1,1)	(1/5,1/3,1)
Z	(1/5,1/3,1)	(1,3,5)	(1,1,1)

Table 19
Pairwise comparisons of alternatives with respect to attribute M.

	X	Y	Z
X	(1,1,1)	(1,1,1)	(1/5,1/3,1)
Y	(1,1,1)	(1,1,1)	(1/5,1/3,1)
Z	(1,3,5)	(1,3,5)	(1,1,1)

Table 20
The total weights of the alternatives.

Alternatives	Final fuzzy Weights – $\tilde{w}_i$	Non-fuzzy weights – F_i	Decision
X	(0.034 , 0.283, 2.703)	1.01	
Y	(0.045 , 0.412, 3.917)	1.46	✓
Z	(0.033, 0.305, 3.079)	1.14	

Then, obtain the fuzzy weight of the ith attribute indicated by a triangular fuzzy number:

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \cdots \oplus \tilde{r}_n)^{-1}$$
$$(Lw_i, Mw_i, Uw_i)$$

After obtaining the fuzzy weight factors $\tilde{w}_i$ according to the Buckley's method, the final are processed from the criteria weights and performance values of each alternative. Finally the fuzzy weight points are defuzzyfiacated by Centre of Area method (Hsieh, Lu, & Tzeng, 2004):

$$F_i[(Uw_i - Lw_i) + (Mw_i - Lw_i)]/3 + Lw_i$$

The matrix of paired comparisons for main attributes is given in Table 3.

If an attribute on the left is more important than the one matching on the right, put your check mark to the left of the importance "equal" under the importance level you prefer. If an attribute on the left is less important than the one matching on the right, put your check mark to the right of the importance 'Equal' under the importance level you prefer.

7. Conclusion

ERP systems have a vital role in today's organizations to realize their vision and strategies. However, they have also high costs and high implementation risks. This study presents an approach to select a suitable ERP system for textile industry. At first, the vision, the strategies and key performance indicators of the organization are checked by using balanced scorecard method. After strategic management phase, the proposed methodology gives advice before ERP selection. According to the company's vision, strategies and KPIs, we can prepare a request for proposal. There is no study focusing request for proposals in the literature to select ERP systems. This study focuses RFPs by using balanced scorecard concept. Then ERP packages that do not meet the requirements of the company are eliminated. The criteria were determined and then compared according to their importance. The rest ERP system solutions were selected to evaluate. An external evaluation team was assigned to select one of these solutions according to the predetermined criteria. The proposed ERP selection methodology was applied successfully for a textile manufacturing company for young people as a real case study. The methodology also gives some suggestions about successful ERP implementation. The proposed methodology can be used for other sectors with some changes.

Decisions are made today in increasingly complex environments. In more and more cases the use of experts in various fields is necessary, different value systems are to be taken into account, etc. In

many of such decision-making settings the theory of fuzzy decision-making can be of use. Fuzzy group decision-making can overcome this difficulty. In general, many concepts, tool and techniques of artificial intelligence, in particular in the field of knowledge representation and reasoning, can be used to improve human consistency and implement ability of numerous models and tools in broadly perceived decision-making and operations research.

The proposed decision support system integrated with strategic management by using BSC may be an alternative to some methods for ERP selection. In this paper, ERP packages and vendors for textile companies were compared using fuzzy AHP. The presented methodology is flexible and can be used for other sectors with some sector specific characteristics changes. Humans are often uncertain in assigning the evaluation scores in crisp AHP. Fuzzy AHP can capture this difficulty. However, Fuzzy AHP cannot support all phases of ERP selection and implementation. Hence, an intelligent decision support system or expert system can be added when gathering data for selection process. Also, the expert system can be used before and after the ERP system selected. The lessons from this textile firm case or other applications can be added into the knowledgebase of the expert system. The expert system can also help to prepare a more detailed request for proposal for a textile firm, because this stage needs experience about the selection process.

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