

# Fuzzy Characterization of Qualitative Variables for the Development of an Overall Efficiency Index of Competitiveness: Using a Modified Triangular Membership Function.

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**Abstract.** Currently it is extremely important for businesses to identify their strengths and weaknesses in the presence of competitors and open global markets; for which, there is interest in determining the level of competitiveness that companies can achieve and how define and prioritize the improvement actions for the sustained growth. This paper presents a modified triangular membership function for the application of fuzzy variables will be considered in determining an overall indicator of competitiveness. The proposed model generates a strategic profile of the company which is a graphic representation that reflects the valuation given as a fixed scale for each aspect of the different functional areas identified as most relevant. This is the initial part of a research project that will include the development of a competitive model for diagnosis and prediction using a fuzzy approach and evolution strategies for optimization and contrast with the field data.

**Keywords:** Competitiveness, overall index, quantitative variables, fuzzy variables.

## 1 Introduction

The interest in determining the competitiveness of businesses has generated numerous researches that are focused on different groups of variables. Some variables examine the strategic management of information for acquiring a competitive advantage in order to maintain flexibility and business innovation [1]. Emphasizes the creation and sustenance of knowledge from internal and external business environment, rather than intervening directly to the operational characteristics of the company. Given that information and its management are necessary to provide a competitive advantage, business strategy focuses on knowledge management tools and methods. As suggested in [2], the dynamics and distribution of knowledge and skills can result in a competitive advantage.

The success of the strategies, especially in the long term, it does not derive from the setting of a business intention and mobilization around this. The company should seek the ability to realize the strategies that create competitive advantage, which depends on its ability to attract and absorb resources and knowledge about the relationships between companies, customers and suppliers.

Companies must obtain information to create competitive differentiation, generating strategies that generate value added [3], focusing on the adaptation needs of the company's internal efforts and external from the market, noting proposals that give value added to the company:

- Leadership on products, i.e., differentiation based on product innovation and qualities of the product;
- Linking with clients, i.e., differentiation based on innovation and customer service;
- Leadership in cost, i.e., differentiation based on operational excellence and solutions fair value.

This implies that more value to the customer must be created, or even customer value must be redefined, considering a service strategy.

### 1.1 Review of literature

Researchers found that new product development (NPI) and its introduction into the market play an important role in shaping a strategy for a company and achieving its objectives [4]. Developing a sustainable competitive advantage in introducing new products is regarded as a visionary in business

strategy. However, the strategic development and financial analysis are crucial for the introduction of new products because the capital invested can not be accurately assessed in terms of its profitability in the future. Therefore, these factors must be considered in the modeling of uncertainty to improve decision-making.

Other factors affecting competitiveness are related to product demand from customers [5]. Therefore the speed, flexibility, quality and cost are becoming increasingly important in the rapidly changing competitive environment. The evaluation of suppliers and a selection process for them is essential to improve the performance of an enterprise and its supply chain, having to be considered from the strategy of products development.

In the evaluation of suppliers should consider the attributes, the correlation with the lifecycle of products, the cycle time of processes and supplier relationships in the long term, because in a market that changes rapidly, Companies must carefully manage its product lifecycle.

The criteria of competence in general differ during different phases of the product life cycle; for example, availability and technology are needed in the introduction phase; costs, quality and speed are required at the stage of maturity.

Within any new product development, point of departure is the definition of customer requirements, thus, competitive factors [6] influence the direction of substitute products over the attributes that customers find important.

The introduction of new products or processes [7] must be conceived as a case of innovation, which represents a body of knowledge of supply and processing activities undertaken by a company. It also represents the beginning of a process of value creation that may result in an improvement in the performance of entrepreneurial innovation.

An important factor for competitiveness is the performance of employees [8], requires a participatory approach that can be used in the workplace to make continuous improvement. To accomplish this, is to determine the procedure or process by which participants should develop its activities during the stages of a process of change.

Based on the above, we define a characterization of qualitative variables in a fuzzy approach which are employed in the definition of an overall efficiency index of competitiveness. The use of triangular functions are commonly applied in literature do not provide a proper coupling of the membership function with the semantic definition of the qualitative variables; this paper proposes a modification of the triangular function to be analyzed and discussed. The paper is organized as follows. Section 2 presents the proposed methodology to define the variables of the model. Section 3 describes the general outline of the overall efficiency index of competitiveness. Section 4 presents the definition of variables in the model. Section 5 shows the results obtained by applying the evaluation model to various companies participating in the study. Section 6 presents conclusions and future work.

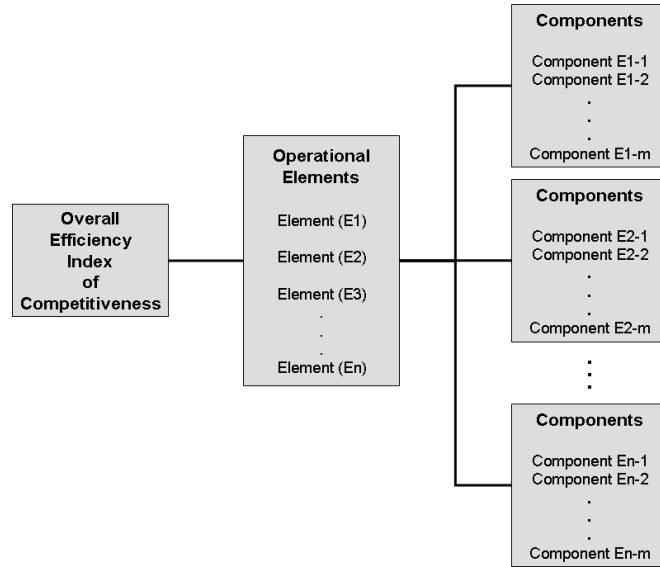
## 2 Methodology

The process to define the variables used to determine the overall indicator of competitiveness is under triangulation of data obtained from different companies to identify those factors that include the main functions of operation and administration. Qualitative variables are treated under the definition of fuzzy variables that are correlated to a self-assessment system used within a group of participating companies.

The model generates a functional analysis that identifies and describes the key variables that are specified on the strengths and weaknesses of the company, developing a strategic operating profile, which has as main objective, assess the potential of the company in each of the key variables, so as to make more clear their activities should be concentrated where the actions and strategies to achieve a sustainable improvement of key aspects of the company to reach a level of world-class company.

The development of the preliminary model shows in figure 1 is based on defining the elements required by the company to determine their level of competitiveness. Are two functions:

- Function of overall efficiency index, as a function of the elements that belong to the productive process.
- Composite function by the components of each element.

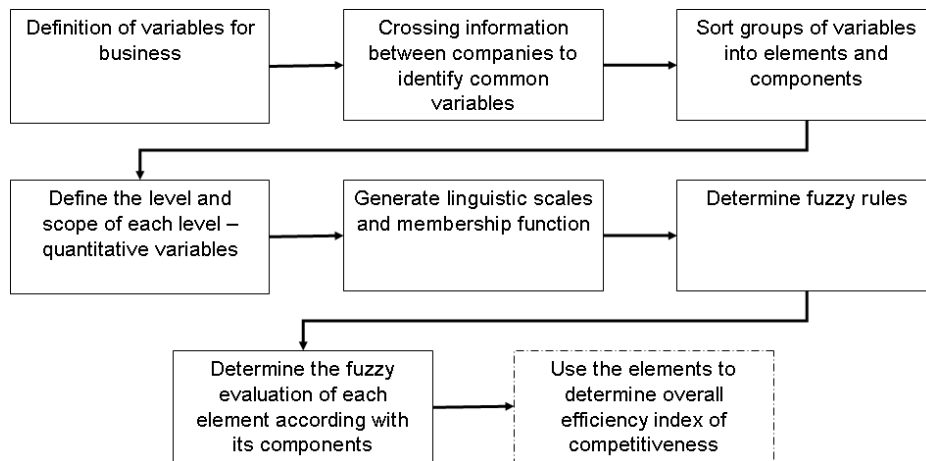


**Fig. 1.** Formation of the Overall Efficiency Index of Competitiveness

The generated model can be made graphs to show the profile analysis of strategic operations of the company that reflects the valuation given as a fixed scale for each aspect of the different functional areas identified as most relevant.

The overall efficiency index is defined on a scale applied to the image of the function that generates meaning on the diagnosis and predictions to be made to assess both the elements and their components.

In the case study, the preliminary model is considered to determine the scale applied to the overall efficiency index, pointing the elements that must implement the actions to be referred within the strategic operational planning.



**Fig. 2.** Process to determine the overall efficiency index of competitiveness (Flow down).

The approach of the composite functions determines the evaluation of components and elements to define the group of variables in each of the evaluated companies. The process defined in Figure 2 is incorporated into the overall model development.

### 3 Overall Efficiency Index of Competitiveness

The overall efficiency index in this case is determined by a scale of 5 levels, under the following definitions:

Develop the selection of elements, which in the case of participating companies can generate a standardized model for the exchange of best practices.

Therefore, the development of the strategic profile, as has been done within the participating companies basically consists of two parts:

- Develop a list of variables - Factors are the key issues that will be analyzed to diagnose strengths and weaknesses of the company. Identification comes from the functional analysis.
- Evaluation of these variables – It is to assess the behavior of these key variables.

For this, choose to use semantic scales of five positions so that the closer to 1 is a variable, is major source of weakness for the company, whereas the more close to 5, more clearly represent a of strength.

This initial assessment is obviously subjective and qualitative, and to be performed by the senior management of the company as perceived at that time to have the character or the situation of each analyzed variable.

**Table 1.** Characteristics of the semantic scale for overall efficiency index of competitiveness.

Overall Efficiency Index	Level				
	1	2	3	4	5
	<b>Highly Negative</b>	<b>Negative</b>	<b>Balanced</b>	<b>Positive</b>	<b>Highly Positive</b>
OPERATIONAL BUSINESS STRATEGY	Operations strategy is not functional, It can not be competitive with the competition	Operational Strategy fails to meet the committed results	Operational Strategy can meet the targets	Operational Strategy exceed targets in a sustainable way	Operational strategy allows to drive the market
STRENGTHS AND WEAKNESSES	Companies where there is no possibility of meeting the objectives	Companies where their weaknesses limit the achievement of objectives	Companies that the balance between their strengths and weaknesses in achieving goals and face competition in a sustainable way.	Companies that allow their strengths to lead the market with predictive actions against competition in a sustainable way.	Companies where their strengths allow to innovate and market competition
ACTION PLAN	Take actions for change, under a new organizational strategy	Its priority must be to improve the level 1 components, and react to reduce their operational and transactional problems	Its priority must be to keep the weak level 3 components for a sustainable growth	Its actions to increase their strengths in a sustainable manner.	Solidify its strengths and renew its functional structure according to Generational Plan (long-term vision)
Type of Company	<b>Companies in decline in global markets</b>	<b>Companies in restructuring</b>	<b>Average Companies</b>	<b>Growing Businesses</b>	<b>World - Class Company</b>

On the analysis and proper assessment of the resources and capabilities of an enterprise, the problem appears on the way in which operationally can be competitive against competitors trying to match at least, their competitive positions.

In this sense, the model can be viewed as a competitive analysis that can assimilate the strategic diagnosis - both internally and externally - through which it is to reflect the competitive position of the company itself and the closest competitors to know concerning the advantages or disadvantages.

The external analysis can be developed with the methodology of benchmarking using the same model on the observations and competitors. This method part of the basic idea that is not enough to make things right, but should do better than competitors. The application of this technique and analysis procedure involves essentially four steps:

- Identify the activities or business functions that need improvement.
- Identify companies that are world leaders in each of these activities or functions.
- Build relationships with these companies, visit and talk with their managers and workers, and so on. To examine first-hand how it is possible to do so as well.
- Use this learning to redefine goals, redesign processes and changing expectations about the functions and activities.

While a conventional competitive analysis is an excellent diagnostic tool for external, applying the model to assess as it is a benchmarking process to overcome competitors.

### 4 Definition of elements and components

After reviewing elements of the theoretical model on a particular case the components are defined, determining the level of development for each value of the semantic level of the overall efficiency index.

Each element is represented by a fuzzy variable, under a scale of 1 to 10. And that group of components in each element determines the fuzzy set of entries in a scale of 1 to 10, rescale it to a table of values of 5 levels, under the following relationship. In figure 3, the first component of the element “Leadership and Commitment” is transformed in a set of equivalent membership functions.

1.0 Leadership and Commitment					
Component	Levels				
	1	2	3	4	5
1.1 Deployment of competitive systems	Competitiveness system is known by the management team of the Business.  The organization has not conducted its assessment of their position in the competitive model	Self-evaluation of competitive system was conducted but have not communicated the results to all levels of employees.  It defines the elements that are the business priorities.  The competitive system has been disseminated at the level of managers, supervisors and department heads.	The system has been released to the supervisor level and facilitators.  The results of the self-assessment have been communicated to all employees.  It has set targets for profitability and targets for all indicators of the business scorecard. (BSC)  The staff employee has been informed of the goals to achieve in these indicators.  There are specific plans and projects, as defined by the Self Assessment.	It has spread the competitive system to all workers with the use of different media, in simplified form, they know the system and how they participate in their work areas.  Employees and operators understand the actions of the system of competitiveness and they are aware of how they participate in achieving the goals of the indicators that they are involved.	There is a clear understanding of how outcomes are linked workspace with the results of the overall efficiency index of competitiveness and Balanced Scorecard indicators (BSC).  All employees know the goals to achieve, progress and action plans to address the priorities found in the self-assessments and participate in continuous improvement projects through work-teams.

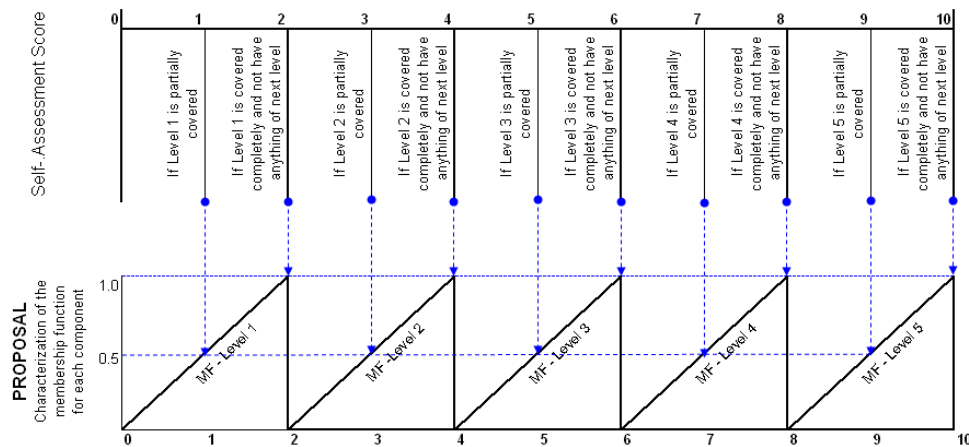


Fig. 3. Relationship between the qualitative variable and Membership Function for a component.

Each component is scored individually using a scale of 1-10. Two possible ratings for each of the 5 semantic levels. That is, grades 1 - 2 to level 1, grades 3 - 4 for level 2, grades 5 - 6 for Level 3, grades 7 - 8 for level 4 and 9 - 10 for level 5.

- Level 1: 1 If it is partially covered: 2 It is covered completely and not have anything of next level
- Level 2: 3 If it is partially covered: 4 It is covered completely and not have anything of next level
- Level 3: 5 If it is partially covered: 6 It is covered completely and not have anything of next level
- Level 4: 7 If it is partially covered: 8 It is covered completely and not have anything of next level
- Level 5: 9 If it is partially covered: 10 It is covered completely.

The preliminary model uses a proposal of membership functions that is consistent with the definitions of each component. It creates a right triangle to the membership function, which differs from the common form of this type of triangular functions as shown in the figure below.

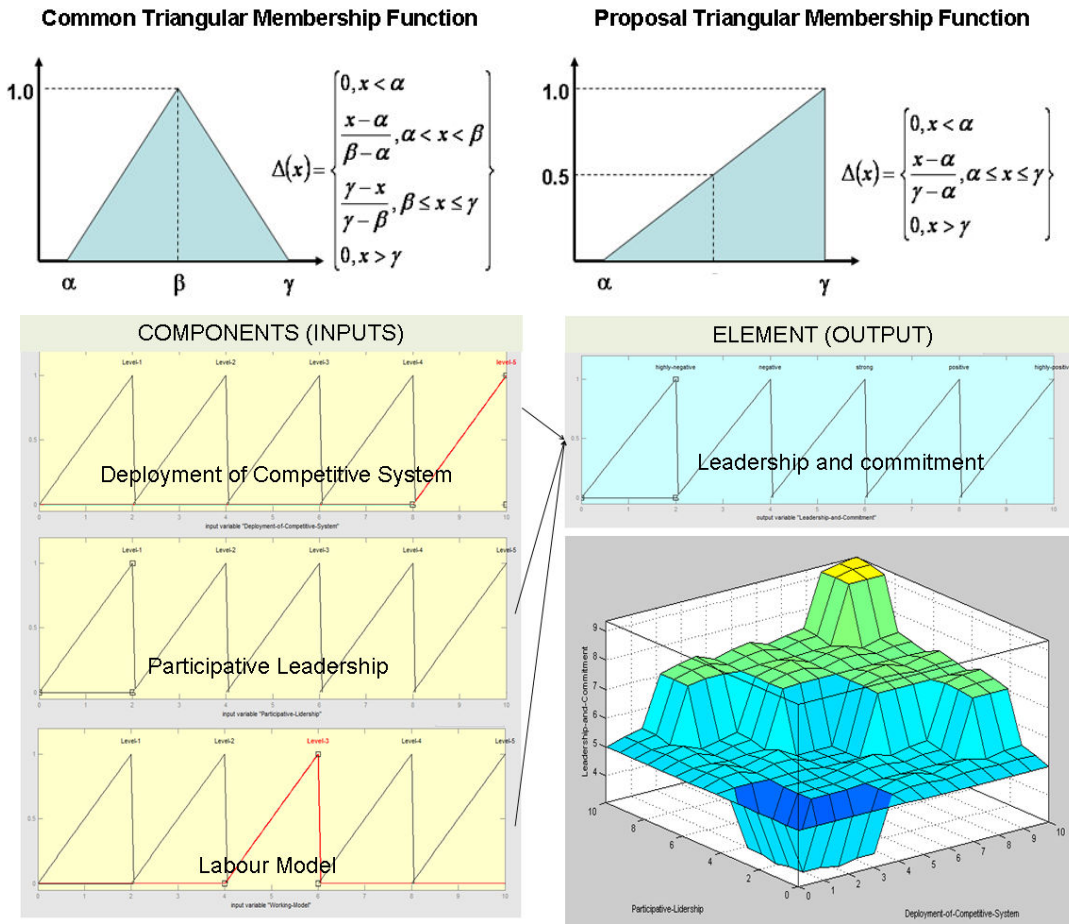


Fig. 4. Triangular Membership Function (above). Diagram of fuzzy inputs to one element (below).

The model identifies 10 elements of output, and 35 components that form the group of fuzzy inputs to the system. The interest of using this model is to generate a diagnosis that can be contrasted with the self-assessment and to define future states to address performance improvement actions on the priority elements. In Table 2 presents the list of elements and components included in the model.

In this evaluation process, the fuzzy rules are structured in the IF part and THEN part. The IF part is the relationship between the components of each element, and the THEN part is the computational result of the evaluated element. The number of rules is equal to the  $5^k$ , where 5 is the number of level and k is the number of components of the element under investigation. Example in figure 4, the element “Leadership and commitment” has three components; the number of rules are 125.

**Table 2.** Elements and Components considered in the General Model of Competitiveness.

ELEMENT	DESCRIPTION	COMPONENTS
<b>1. Leadership and Commitment</b>	How to develop the visionary leadership, participatory and ethical, to create a culture that sustains the competitiveness and viability of the organization over the long term.	1.1 Deployment of competitive system 1.2 Participative Leadership 1.3 Labour Model
<b>2. Safety, Health and Environmental Protection</b>	How the company improves satisfaction, health and welfare of their staff at work and the work itself, supporting the safety, hygiene and ergonomics at work, improving the working relationship with staff.	2.1 SOS GIS
<b>3. Markets, Customers and Consumers</b>	The way the company develops its knowledge about the needs and preferences of its customers, end-users and markets in the short and long term, as well as opportunities to anticipate the expectations of its customers and its position against competitors, including how the company evaluates its market share, customer satisfaction and customer loyalty.	3.1 Knowledge of customers and markets 3.2 Knowledge of regulations and compliance 3.3 Proposal for customer value 3.4 Assessment and improvement of customer satisfaction
<b>4. Teamwork</b>	Results of value created for its staff and its causal relationship to the improvement of its processes, systems and competitiveness of the organization. The value created for staff, including individual and group participation, development and growth of personal satisfaction at work, job stability and recognition.	4.1 High Performance Teams 4.2 Improvement Project 4.3 Multi-skills
<b>5. Integral Value Chain</b>	How the organizational goals and strategies are deployed in the organization to establish operational goals and action plans in all areas and processes to ensure alignment with strategic objectives. Development of indicators of efficiency and / or effectiveness to ensure achievement of consistent levels of performance, addressing opportunities for improvement and innovation.	5.1 Manufacturing Value Stream Map 5.2 Commercial Value Stream Map 5.3 Administrative Value Stream Map 5.4 Deployment of the value proposal. 5.5 Assessment and improvement of customer satisfaction
<b>6. Development of Products and Services</b>	The way the company creates competitive advantage through the design of products, services and processes to respond to and anticipate the needs and expectations of customers and users	6.1 Development and implementation of new products 6.2 Design of Lean Processes
<b>7. Optimization of Equipment and Processes</b>	The way the organization designs, manages and improves its processes for the performance of products and services that meet the needs and requirements of customers, and developing improvement strategies for value creation.	7.1 Elimination of Wastes 7.2 Process Ability 7.3 Optimization of Constraining 7.4 Autonomous Maintenance, TPM 7.5 Reliability of equipments, TPM 7.6 Visual Management
<b>8. Adapting to the demand. (Flow)</b>	The way the organization delivers its products and services through competitive processes to meet the requirements, needs and expectations of their customers, users and markets and achieve the strategic objectives of the organization.	8.1 Production Planning (demand) 8.2 Pull system 8.3 Flexibility and rapid changes 8.4 Inventory optimization
<b>9. Competitive Sourcing Program</b>	The way the organization designs, manages and improves the inputs required to generate products, services and processes, as well as the development and selection of suppliers, creating strategies and actions of mutual support and benefit for the creation of value.	9.1 Supplier Development 9.2 Supply of Material and Components 9.3 Integration 9.4 Energy Management
<b>10. Knowledge Management</b>	How to obtain, structure and communicate information and knowledge for the management of the organization to support the achievement of strategies, and developing mechanisms to encourage the creation of knowledge with practices of innovation and creativity, sharing of best practices and stimulate the technological development.	10.1 Standarization 10.2 Information Management al Knowledge Organization 10.3 Development of Organizational Skill

The proposal is based on developing a strategy that may improve the assessment of factors influencing the functional areas which may be related to the comments of stakeholders, generating a self-assessment method to recognize performance problems and causes underlying these inefficiencies.

The function of the variable base is made using a proposal of a modified triangular distributions; this would represent the categories of judgments of experts similar to the functions in figure 4.

## 5. Results from field data.

The development of fuzzy variables in the model will be compared with the results obtained by the self-assessments in different companies. Until now there have been two self-assessments of the competitiveness model, applied to 12 production plants at Northern Mexico, obtaining the following results, figure 5.

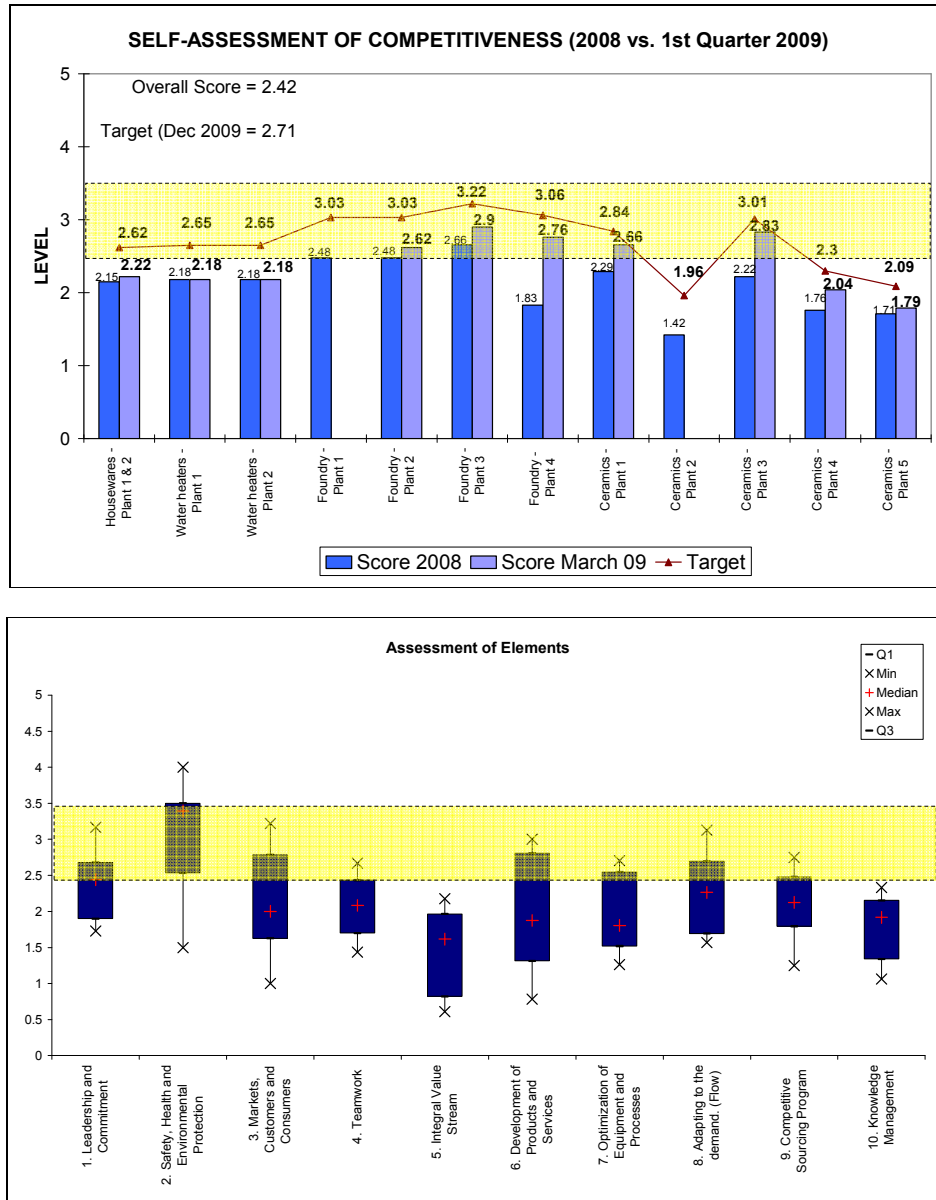


Fig. 5. Assessment of competitiveness (above), assessment of elements (below)

The first evaluation of the model was used within the strategic planning of business to develop actions to increase the competitiveness of the companies. Evaluate the probability of success in different scenarios to reach the objectives and check their progress at the end of first quarter 2009. Decisions made: - No actions in business 2 and 3 to determine the effect of natural growth, where the assumption is that there will be no change. In the Foundry Plant number 4 generated the most aggressive plan of activities to achieve higher growth. In the ceramic business, decision was made to close the plant number 2 and divide the production among 4 remaining plants to improve production flows. The behavior of the elements shows that there are areas of opportunity to achieve at least a Balanced level (Score 3). The biggest breakthrough is in the security element.

The preliminary model, using a fuzzy approach must be contrasted with self-assessments, generating a pattern of diagnosis and prediction, which determines the selection of elements and components which must be focused improvement activities to increase business competitiveness



## 6 Conclusions and Future Researches

The implementation of the proposed model would identify opportunities to improve in the areas of operation of the companies involved, creating an often self-assessment that will allow strategic planning actions and monitoring activities or forwarding activities at the end of each semester.

The study develops the selection of variables in the application of a semantic interval scale, where the measurement and evaluation processes are different levels of information on the functional areas that affect business competitiveness.

The process to define fuzzy variables presented in this article is applicable to any industry and any set of variables. In that sense, there are two main areas that should be of interest to administrators.

First, the model can be used to define the competitive elements that identify the strengths and weaknesses of companies and to define the lines of action within its strategic planning. This study provides a key focus for the selection of a group of variables and their treatment under the denotation of fuzzy variables, giving a reasonable response rates that are used to determine the overall efficiency index of competitiveness. Generate a process of benchmarking between companies of a different nature in the objectivity of the groups of variables.

Second, a better understanding of the dynamics of substitution of activities to be developed to reduce their weaknesses, and ensure that functional areas achieve the performance level of the company. For example, actions which take place in new product development, process optimization and prospective suppliers can generate an individual improvement, but there will be no changes in the competitive aspect, if not identified the interactions among them and finding solutions in integral manner.

In future research, the main focus of interest is the application and validation of the proposal fuzzy model, including the impact of the indicators of competitiveness in business growth and productivity, given the marginal effects of the decision variables used, considering the use of a fuzzy approach and evolution strategies for optimization and contrast with the field data. The use of variables to define the activities in different functional areas and determine the impact of carrying out such actions, by controlling the factors associated with the independent and dependent variables through the allocation of participants, under synchronous and asynchronous evaluations which show that the results of use of an overall efficiency index of competitiveness can determine how different confidence levels have an effect on the selection of variables and they show improvement activities that will increase business competitiveness.

## References

1. Pollalis, Y.A., Dimitriou, N. K.: Knowledge management in virtual enterprises: A systemic multi-methodology towards the strategic use of information. *International Journal of Information Management* 28, 305–321 (2008).
2. Helfat, C., Raubitschek, R.: Product sequencing: Co-evolution of knowledge, capabilities and products. *Strategic Management Journal* 21, 961–979 (2000).
3. Matthyssens P., Vandenbempt K.: Moving from basic offerings to value-added solutions: Strategies, barriers and alignment. *Industrial Marketing Management* 37, 316–328 (2008).
4. Tiwari A., Vergidis K., Kuo Y.: Computer assisted decision making for new product introduction investments. *Computers in Industry* 59, 96–105 (2008).
5. Chang S., Wang R., Wang S.: Applying fuzzy linguistic quantifier to select supply chain partners at different phases of product life cycle. *International Journal Production Economics* 100, 348–359 (2006).
6. Wagner E. R., Hansen E. N.: A method for identifying and assessing key customer group needs. *Industrial Marketing Management* 33, 643–655 (2004).
7. Roper S., Du J., Love J.: Modelling the innovation value chain. *Research Policy* 37, 961–977 (2008).
8. Vink P., Imada A.S., Zink K.J.: Defining stakeholder involvement in participatory design processes. *Applied Ergonomics* 39, 519–526 (2008).