Design of an artificial intelligence system for predicting success of new product development and selecting proper market-product strategy in the food industry

RESEARCH ARTICLE

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Abstract

Predicting the performance of the new product development and selecting the strategy in the case of new product development failure is an issue that has drawn the attention of the many managers. Therefore, the goal of this study is to design an integrated system of prediction of product development success and selection of a proper market-product strategy by the method of artificial intelligence in companies working in the food industry. The population of this study was 250 companies of the food industries in Iran. The inputs and outputs of the success of the new product development were obtained from the research literature. Moreover, Ansoff matrix was applied to select the market-product strategy. A questionnaire was used to collect the data in this study. The adaptive neural-fuzzy network method and the fuzzy inference system are used to analyze the data. The results show that the Chief Executive Officers of companies working in the food industry may take action to predict a new product development success before developing the new product and use alternative strategies if needed.

Keywords: new product development, market-product strategy, ANFIS, FIS, food industry

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1. Introduction

The increased rate of technological changes, intense competition, dynamic needs of customers and low demands for the outdated but available products has led to a shorter product life cycle (Ho and Tsai, 2011:6498). To succeed in the current turbulent business environment, the potential of the organizations for developing new products is an important aspect to be considered (Sheng et al., 2013:2355). Any organization, regardless of its size, motivation and profit, looks for new product development based on industry or trade pressures (Shakib, 2016). Therefore, the development of a new product is a strategy that maintains the current duty and function of the organization and it improves some performance indicators of the organization’s duty by developing products involving new and different qualities (Ansoff, 1957).

Success of new products is considered to be the best element of a company survival or success of (Harmancioglu et al., 2009; Lisboa, 2011; O’Cass et al., 2014). The food industries are not exempt from this either. In this industry, there is a rapid change in customers’ tastes and use of new technologies just like other industries (Stewart and Martinez, 2002).

The existing dynamic conditions are forcing the food producing companies to continuously develop new products (Suwannaporn and Speece, 2010). Consequently, great efforts were made in the last decade to identify factors that affect the success of new product development efforts (Lemmerer et al., 2015). However, the studies show that as a result of product failure, many of the previous investments in new product development in the food industry has been lost in the market. It is reported that the failure rate of new food products is between 70 to 80% (Winger and Wall, 2006). According to these studies, it is estimated that the cost of failure in the American food industry is up to 20 billion dollars due to inappropriate development of new products. In this industry, around 80 to 90% of the products that are introduced to the market face failure in the first year (Rudolph, 1995).

Since the failure of new products has high costs for the organizations in practice, the necessity of planning with a competitive approach has led companies to apply appropriate approaches in the path of competition. Development of new products is considered as a competitive strategy through which companies want to improve their products competitively. Meanwhile, artificial intelligence and decision support systems help decision makers, particularly the managers of food industry, to avoid high expenditures for product development.

Artificial intelligence systems are able to help managers with decision making and adopting proper strategies in any stage of new product development especially at its early stages. Within many new product development activities in the food industry, managers, try to develop new products regardless of the capabilities and potential of the company and just due to market pressures. This in return could lead to the failure and loss of plenty of company resources. However, proper decisions can be made by the help of artificial intelligence and backup systems and perceiving the capabilities of the company as well. In the case of need, also the development of the new product can be delayed until the appropriate time and alternative strategies can be adopted instead to enhance the company’s capabilities and potential. This paper is also structured to provide food industry managers aware of the success of the new product development process in the early stages of developing a new product. Thus the manager could use alternative strategies if necessary. The proposed approach is based on an artificial intelligence system along with different stages.

This requires using appropriate techniques and methods of decision-making and identifying the factors that affect each of these strategies. Fuzzy set theory is an approach for modeling the uncertainty by using membership functions. On the other hand, Fuzzy inference system and adaptive network-based fuzzy inference system as sub-branches of artificial intelligence have attracted noticeable attention in the field of modeling and prediction. This popularity may be attributed to the great capability and potential of these systems for modeling and prediction, specifically, in the case of complex processes. Artificial intelligence is the name used for systems which may have similar reactions as intelligent behavior of human beings. Examples are
perceiving complex situations, simulating thought processes and human reasoning methods and successful response to them, knowledge learning and acquiring ability and reasoning ability for solving problems.

As discussed above, the goal of this study is addressing lack of proper systems that predict new product development function and systems which may offer the market-product strategy. Therefore, by perceiving the case and the importance of predicting success of new product development efforts, this research study seeks to design an appropriate system for predicting success of new product development efforts and a suitable fuzzy inference system to select a proper market-product strategy by using Ansoff’s (1957) work. Ansoff growth matrix provides us with a task-based taxonomy which is the basis for classifying strategic choices. Indeed, the Ansoff matrix helps strategists define the area and domain which an institution tends to follow.

The aim of the current study is to offer an effective tool for the managers of the food and beverage industry, so that it provides an appropriate system for decision making and decision taking in the field of the new product development and selecting the proper strategy. Therefore, in this paper, first literature on the new product development and the factors that affect its success, market-product strategy, adaptive neuro fuzzy inference system and fuzzy inference system is reviewed. Then, the Adaptive Network-based Fuzzy Inference System (ANFIS) design approach and fuzzy inference system is described in order to predict success of new product development efforts and to select the product market strategy, respectively. Finally, predicting score of new product development is calculated based on ANFIS and the output of this section is considered as an entry of the Fuzzy Inference System. Then, appropriate strategies for any manager of the food and beverage industry is introduced by using the fuzzy inference system which is designed based on product-market Ansoff matrix.

2. Literature review

2.1 Factors that affect success of new product development efforts

The lack of product innovation and high dependency of manufacturers on their products are suggested as the major reasons of failure of development of products that do not last for more than two years. However, truly innovative products, which form less than 2% of the food industry, have achieved 25% rate of success in the market (Khan et al., 2017).

Identifying the factors that contribute to success of new product development efforts in terms of business strategies has prompted researchers to do extensive studies in this context. Studies about the evaluation of factors that affect success of new product development efforts indicate various different results. Table 1 shows briefly the influencing factors on the success of new product development in various researches.

Lindman et al. (2008) is the most comprehensive research in terms of the influencing factors on the success of new product development among the reviewed studies. This study has a general overview and considers all the aspects of the influencing factors on the development of the product and the inception of the new product development process until its introduction to the market. These eight factors are long-term and systematic outlook, the technology approach, the design approach, the market approach, the resource approach, the efforts made in the context of the new product, the conceptualization of the new product and new product management.

In addition to research on the factors that affect the development of new products, there are some other research works that have used various indices to measure the effectiveness and efficiency of new product development activities. O’Cass et al. (2014) used four indices of access to expected income goals, expected market share, expected growth and expected profitability to measure the performance of new product development efforts. Besides, the factors assessing the success of a new product development are also examined in some other studies as shown in Table 2.
Table 1 shows the influencing factors on the success of the new product development, while Table 2 shows the indices of the evaluation of the product development success. Although, in the matrix of the market-product, the development of the new product is considered as a competitive strategy, it is not the only strategy available. Furthermore, there are some alternative strategies in the Ansoff matrix that they can be used instead of the new product development.

| Researcher(s)                  | Factors influencing the success of new product development                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cooper and Kleinschmidt, 1995 | High quality of new product development processes, explaining new product development strategies for business units, sufficient resources including money and people, research and development, new product development team with high quality, top managers’ commitment, environment and culture of innovation, use of multitasking teams and accountability of top managers for the results of new product development efforts. |
| Lynn et al., 1999             | Structured process, a distinct and clear insight, a revision of the product after launching it to the target markets, a long-term vision, optimizing the skills of product development teams, understanding the market and its dynamics, top managers’ support, applying gained experience from previous projects, providing and supplying a good team, and being able to keep experienced team members for developing the project. |
| Langerak and Hultink, 2005    | Participation of customers, raising the rate of activities and tasks, reducing the size and the components, training and rewarding employees, applying supporting systems and backup techniques, stimulating the inter-task coordination, focusing on customers and simplifying the organizational structure are accelerators of success of new product development. |
| Dhamvithee et al., 2005       | Perfect ways of developing a new product, multitasking communication and the competence of the companies.                                                                                                                                                                                                                                                                                   |
| Sun and Wing, 2005            | Precise definitions of the target market (the formation of original ideas and concepts), application of qualitative standards, and clear goals of the projects and consideration of important points in the early stages. defining and specifying the product in the second stage, internal communication in the project team, primary presentation and its development, delivery of the product at the right time, launching the product timely, cost of production and product commercializing. |
| Kandemir et al., 2006         | Advantages of the product, definition of the product and required knowledge before product development, technological synergy, and marketing.                                                                                                                                                                                                                                                     |
| Mu et al., 2007               | Technological, marketing, managerial and commercializing factors.                                                                                                                                                                                                                                                                                                                             |
| Lindman et al., 2008          | Efforts are long-term and systematic outlook, the technology approach, the design approach, the market approach, the resource approach, the efforts made in the context of the new product, the conceptualization of the new product and new product management.                                                                                                                                                                                     |
| Suwannaporn and Speece, 2010  | Available research in the market for evaluating the product samples, leading the research and development projects, assigning the status and price and applying before starting new research and development projects.                                                                                                                                                                                     |
| Ho and Tsai, 2011             | Innovation value and processes quality.                                                                                                                                                                                                                                                                                                                                              |
| Younesi and Ayseli, 2015      | Innovation of food products.                                                                                                                                                                                                                                                                                                                                                           |
| Kettunen et al., 2015         | Intensity of competition and the degree of market innovation.                                                                                                                                                                                                                                                                                                                            |
| Esbjerg et al., 2016          | Role of food retailers in product innovation.                                                                                                                                                                                                                                                                                                                                        |
| Shakib, 2016                  | Strategic approach, marketing strategy, and market research activities.                                                                                                                                                                                                                                                                                                                  |
| Khan et al., 2017             | Market, product, process and organizational approaches.                                                                                                                                                                                                                                                                                                                             |
2.2 The market-product strategy

The ultimate goal of the market-product strategy is to select a good market in which the organization may compete (Morgan et al., 2003). In the literature published on strategic management, it is claimed that business strategies shape the selection of the market-product scope (Rajaratnam and Chonko, 1995). The most essential concepts and perspectives of strategic planning and the strategy of a company are introduced in Ansoff’s (1957) work (Veiga and Franco, 2015). Ansoff (1957) presented a model which is known as the market-product growth model to help discover new opportunities for intensive growth. Based on this model, four strategic options for development and growth are presented to a company. These options are shown in Table 3 (Ansoff, 1988; Colovic, 2012; Gessinger, 2009; Kotler et al., 2009).

- Market penetration (available product-available market): the companies are attempting to raise their share of market products and current services through marketing efforts. In other words, this strategy means staying in the current market by using current products and making efforts to expand the market share. Market penetration includes actions like raising number of sales assistants, increasing advertising expenses, promoting extensively for raised sales and enhancing communication and advertising.

- Product development (new product-available market): in this strategy, the company is attempting to raise its sales by improving or modifying its products and current services.

- Market development (available product-new market): this strategy is applied when the managers are deciding about new markets. The aim of this strategy is to present new products or services to new geographical regions. Based on this strategy, companies get involved in new markets to raise their sales by presenting products there by relying on their existing capabilities for producing products.

- Diversification (new product-new market): in this strategy, companies present new products in new markets. This strategy is only justified when there are good opportunities beyond available products and markets.

Table 4 shows the factors that affect the selection of market-product strategies and corresponding market-product strategies consistent with the organizations’ position. The table indicates the conditions and features of the selection of any market-product strategies for the company and its market.

Table 3. Various market-product strategies.

| Product      | Market                  | The available market       | The new market          |
|--------------|-------------------------|----------------------------|-------------------------|
| Available products | Market penetration strategy | Market development strategy |
| New products  | Product development strategy | Diversification strategy |

Table 2. The criteria for evaluating success of new product development efforts.

| The evaluation of the new product development function | Researcher(s) |
|--------------------------------------------------------|---------------|
| The access to sales growth                             | Huang et al., 2004; O’Cass et al., 2014; Song and Di Benedetto, 2008 |
| The access to revenue targets                          | Huang et al., 2004; Langerak and Hultink, 2005; O’Cass et al., 2014; Oh et al., 2012 |
| The customers’ approval                                | Huang et al., 2004 |
| The customers’ satisfaction                            | Huang et al., 2004; Millson and Wilemon, 2005; Oehmen et al., 2014 |
| The access to achieved product goals                   | Huang et al., 2004; Oehmen et al., 2014 |
| The access to the market share targets                 | González and Palacios, 2002; O’Cass et al., 2014 |
| The access to the profitability goals                  | O’Cass et al., 2014 |
Table 4. Factors that affect selection of market-product strategy (Basu, 2014:29).

| Characteristic of market/products | Strategy          | Factors that affect the selection of market-product strategy                                                                 |
|-----------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Available market/available product| Market penetration (MP) | • The growth of products (per available customers and new customers) (MP1)  
• Personal advertising and selling to available customers (MP2)  
• Market balance and ownership (MP3)  
• Competitive prices and discounts offering (MP4) |
| New market/available product      | Product development (PD) | • Raising the research and development and innovation attempts (PD1)  
• More attention to customers’ needs (PD2)  
• First movers in a product category (PD3)  
• Raising the overall efficiency of consumers (PD4) |
| Available market/new product      | Market development (MD) | • New distribution channels (MD1)  
• Modifying the available products for the use of new customers (MD2)  
• New geographical regions (MD3)  
• Highlighting the new dimensions (MD4)  
• Segmenting the market’s new pricing policies (MD5) |
| New market/new product            | Diversification (DI)  | • New products in the new markets (DI1)  
• The technology and new skills (DI2)  
• Adequate capital-financing models (DI3)  
• The facilities and new business (DI4)  
• High risks (DI5) |

2.3 Fuzzy Inference System

A system which formulates a map from input to output by using fuzzy logic is called a Fuzzy Inference System (FIS). A Fuzzy Inference System provides a systematic process for changing a base of knowledge into a nonlinear map. Since a Fuzzy Inference System is made up of a number of “if-then” terms, such a system is called a rule-based system. Mamdani and Asilian (1975) used a fuzzy inference system to control the combination of a steam engine and a boiler by applying the combination of syntax rules in the human operator’s experiences (Mamdani and Asilian, 1975). The structure of a fuzzy inference system is shown in Figure 1.

Figure 2 shows that a fuzzy inference system consists of three major parts. In the fuzzification stage we consider a membership function for any entered variable and the definite inputs change into fuzzy ones in the fuzzy inference system. Membership functions have various types, such as triangular, trapezoidal, Gaussian, and so on. The membership function of a fuzzy set is a generalized function in classical sets. In fuzzy logic,
this function represents the degree of possibility as an extension of the evaluation. A membership function is a curve that defines how each point of the input space is mapped to a membership value (or a degree of membership) between 0 and 1.

Membership functions were introduced in Zadeh (Zadeh, 1965). In order to fuzzificate input and output variables in fuzzy inference system, the triangular membership function was applied in this study. For the sake of the simplicity of triangular fuzzy numbers, their computational efficiency is very high and they are applied in many managerial, commercial and financial decision makings.

To understand fuzzification better, let’s assume the variable x for which three membership functions $x_1$, $x_2$ and $x_3$ are designated. If the value of x is 7, it can be said that the variable of x with the membership degree ($\mu$) of 0 belongs to $x_1$, with the membership degree of 0.3 belongs to $x_2$ and with the membership degree of 0.7 belongs to $x_3$. That is as same as fuzzification of x=7. This example is illustrated in Figure. 2.

The inference rules indicate how expressive knowledge, knowledge associated with people’s linguistic terms, is changed into existing knowledge in the system and it’s based on if-then rules. Finally, the deffuzification stage exists where fuzzy output is turned into definite numbers. Deffuzification is a process that converts a fuzzy set to a definite number. Therefore, the input of the deffuzification process is a fuzzy set (the result of the collection of the fuzzy sets output) and its output is a number. Fuzzification helps in evaluating during the middle stages while the final output of interest for each variable is merely a number. There are several methods, such as gravity, bisector, half the maximum (average maximum value of the fuzzy set), the largest maximum and the smallest maximum for deffuzification. However, the most common method is the center of gravity (Roychowdhury and Pedrycz, 2001).

2.4 Adaptive Network-based Fuzzy Inference System

ANFIS is used to predict success of new product development efforts. Since this system has combined neural networks and fuzzy logic concepts into one, we can benefit from the features of both in a single frame. ANFIS is based on Takagi and Sugeno (1985) fuzzy inference system. Therefore, in this study the Sugeno’s inference method was used for adaptive neural-fuzzy system. Indeed, ANFIS is a progressive network structure (Jang and Sun, 1995). An example of the Sugeno fuzzy inference system is shown in Figure 3.

It is assumed that the system under study consists of two inputs (x and y) and one output (z) and the rules in this system are as follows (Jang, 1993):

Rule 1: if x is $A_1$ and y is $B_1$ then $f_1 = z$
Rule 2: if x is $A_2$ and y is $B_2$ then $f_2 = z$

Figure 2. The fuzzification of a definite number.
Figure 3. Simple structure of Adaptive Network-based Fuzzy Inference System with two inputs and one output.

x and y show the entries of the Fuzzy Inference System, and A and B show the membership functions which are divided into two membership function in this figure. W shows the output of each membership functions, N is the normalized of the output membership functions and \( \sum \) shows the aggregation of the outputs.

Layer 1: in this layer, the membership level of input nodes to different fuzzy intervals is determined by applying the membership function. \( i \) stands for the index of the rule.

\[
O_{1,i} = \mu_{A_i}(x), \quad i = 1 \quad (1)
\]
\[
O_{1,i} = \mu_{B_{i-2}}(y), \quad i = 3,4 \quad (2)
\]

Layer 2: any node in this layer calculates the activity degree of a rule.

\[
O_{2,i} = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y), \quad i = 1,2 \quad (3)
\]

Layer 3: in this layer, the activity degree of the \( i \)th rule is normalized as follows.

\[
O_{3,i} = \frac{w_i}{\sum_{i=1} w_i}, \quad i = 1,2 \quad (4)
\]

Layer 4: in this layer, the output of each node is equal to:

\[
O_{4,i} = \frac{\sum_{i=1} w_i f_i}{\sum_{i=1} w_i} = \frac{\sum_{i=1} w_i (p_i x + q_i y + r_i)}{\sum_{i=1} w_i}, \quad i = 1,2 \quad (5)
\]

Layer 5: in this layer, the value of the final output, that is the total output of the sum of the previous layer nodes outputs, is calculated as follows:

\[
O_{5,1} = \sum_{i=1} ^\frac{w_i f_i}{\sum_{i=1} \sum_{i=1} w_i} \quad (6)
\]

In this paper, different types of membership functions will be examined at the first layer in order to design an appropriate ANFIS. Then, the best ANFIS is selected by calculating the error indices in the train and test sections.

ANFIS models are usually made up of two parts of train and test. In other words, firstly, a series of data (as train) is entered to ANFIS training. Then, the network learns the desired method of generating output through
inputs based on continuous repetition and learning. After training the system and reducing the errors of the network, it is tested using a part of the data in the next level.

3. Tools and methods

A two-step method is followed in this study, of which the success of the new product in the market is predicted based on the influencing factors on the development of the new product by using ANFIS method in the first step. In the next step, a Fuzzy Inference System is designed to select the market-product strategies of the food industry, one of the entries of which is the success score of the predicted product development from the previous step. How to design any of these models is described below. In this study two questionnaires were used for collecting the date of inputs and outputs.

The first questionnaire was about the factors that affect success of new product development in which Lindman et al. (2008) components including long-term and systematic perspective, the technology approach, the design approach, the market approach, the resources approach, attempts made for the new product, the conceptualization of new product and the new product management were used. In this questionnaire, 52 questions were used in order to measure the eight effective components on the success of a new product development. For example, one of the questions regarding the long-term and systematic outlook component was “This company has a long-term program for new products.” The second questionnaire was about ANFIS output, i.e. the new product development success. The O’Cass et al. (2014) questionnaire applied four measures of access to expected income goals, expected market share, expected growth and expected profitability to measure the performance of new product development. Four of these measures were used as measures of success for new product development in this study. The questionnaires were distributed among all the 393 company managers of the food industry in East Azerbaijan, Iran. Finally, 250 valid questionnaires were returned with a return rate of 63.6%. A summary of the characteristics of these companies is shown in Table 5.

Moreover, a group of experts are used to choose the influencing factors on the selection of the market-product strategy in this research. Within a number of meetings with expert group, they were asked to determine the importance of the influencing factors on the selection of the market-product-strategy based on the paired comparison.

| Characteristics                  | Subgroup             | N  | Frequency | Frequency percentage | Cumulative percentage |
|----------------------------------|----------------------|----|-----------|----------------------|-----------------------|
| Size of company                  | Small/medium         | 250| 212       | 84.8                 | 84.8                  |
|                                  | Large                | 38 | 15.2      | 100.0                |                       |
| Number of staff                  | 1-100                | 250| 129       | 51.6                 | 51.6                  |
|                                  | 101-500              | 83 | 33.2      | 84.8                 |                       |
|                                  | >500                 | 38 | 15.2      | 100.0                |                       |
| Time to do new product development| A year ago           | 250| 144       | 57.6                 | 57.6                  |
|                                  | Two years ago        | 94 | 37.6      | 95.2                 |                       |
|                                  | Three years ago      | 12 | 4.8       | 100.0                |                       |
| Statue of the respondent in the company | Top manager       | 167| 66.8      |                       | 66.8                  |
|                                  | R&D manager          | 39 | 15.6      |                       | 82.4                  |
|                                  | Marketing manager    | 44 | 17.6      |                       | 100.0                 |
| The role of the new product      | The new product is a major part of the sale | 250| 139       | 55.6                 | 55.6                  |
|                                  | The new product is a minor share of sales | 91 | 36.4      |                       | 36.4                  |
|                                  | The new product is a very small part of sales | 20 | 8.0       |                       | 100.0                 |
3.1 Designing Adaptive Network-based Fuzzy Inference System

In this study, the score of success for new product development was predicted for every food and beverage company in the first step by using ANFIS. Therefore, inputs and outputs were determined at first.

The reasons why the input and output variables were selected according to the works of Lindman et al. (2008) and O’Cass et al. (2014) is their comprehensiveness in examining different aspects of factors that affect success of new product development efforts, the understandability and simplicity of the examined measures and evaluating success of the new product development for the sample members, access to a standard questionnaire with appropriate validity and reliability, simplicity of operationalization of concepts and internal stability so that there are no contradictions between the meaning of the concepts.

In order to predict success of new product development efforts, an adaptive fuzzy-neural network with eight input variables and one output variables is designed. The input variables are long-term and systematic perspective, the technology approach, the design approach, the market approach, the resources approach, attempts made about the new product, conceptualization of the new product and the new product management. The output variable is success of the new product development effort as a score. Also, 90% of the data were entered into a designed adaptive neural-fuzzy system as training data in order to estimate an appropriate prediction system and 10% of the data were selected as test data.

To start the study, the designed neural-fuzzy network with various membership functions and two membership functions per input was trained. The aim of the training data is to train ANFIS and obtain the least error between the data entered into the model as the target (T) and data exiting the model as output (Y). In fact, the aim of training the ANFIS is to achieve the desired method of generating output through inputs. Target data, as explained, were measured using the O’Cass et al. (2014) questionnaire and input data was measured by Lindman et al. (2008) questionnaire and then entered into ANFIS. The output will be the output of ANFIS. Since the error between Output and Target decreases with increased training, ANFIS can be trained better. Finally, after each ANFIS training, the test data was entered into the system and the best ANFIS was selected for prediction based on the error indicators and the value of the determination coefficient. In this paper, the best ANFIS was selected to predict the success of a new product development based on the described condition. According to this ANFIS, the success score of new product development was obtained for each company.

3.2 Designing fuzzy inference system to select the market-product strategy

After predicting success of new product development efforts, the Fuzzy Inference System was used to select the market-product strategy in the second step. For designing a fuzzy inference system, the inputs and outputs are determined at first. The team of experts consisted of three CEOs, three marketing managers and two professors. This combination was used in order to avoid multiplicity of variables in selecting strategies when considering experts’ opinion. In paired comparison, the experts were asked to determine the importance of any factors that affect the selection of market-product strategy in each of the related strategies (diversification, market development, market penetration) pairwise according to a 1 to 9-hour spectrum. Eventually, the weight of any factor in each strategy was determined by creating the paired comparison matrixes. The factors that affect the selection of the product market strategy were selected based on the highest weight.

The system had five inputs. The inputs involve: increasing demand for goods (ID), new geographical areas (NGA), enough capital (EC) new distribution channels (NDC) and new product development success (SNPD). One output of the ANFIS was determined to be the score of new product development success and four others were decided by experts’ judgment and paired comparisons. The predicted score out of ANFIS for new product development success was considered as a factor that affects the companies’ initiation for developing the new products. Linguistic terms were phased in the next step of the Fuzzy Inference System. The Triangular function was used for phasing linguistic terms. In this study, triangular fuzzy numbers of all the verbal variables are shown with the symbols ($\alpha, m, \beta$). Taking the research questionnaire into consideration,
a three-itemed spectrum with equal distances was used for phasing date and a five-itemed spectrum was used for inference system outputs. The equivalent linguistic terms and fuzzy numbers for every input are shown in Figure 4 and Table 6. Linguistic terms and fuzzy numbers for every output are shown in Table 7.

- **Developing Fuzzy Inference System rules**

In modeling a system using fuzzy logic, the rules that associate inputs to outputs must be written after defining and determining the number of inputs and outputs. In this step, 243 rules were developed given the fact that there are five input variables which are categorized into three linguistic words. Moreover, these 243 rules were exposed to expert opinion and a decision-making team. Based on the meetings held with the team of experts and asking for their views and upon agreement of all the experts in the meetings, 239 rules were finally confirmed and it was concluded that the developed rules had logical validity. Eventually, the rules were entered into MATLAB (version R2016a, Mathworks, Natick, MA, USA). For example, one of the rules is stated follows:

![Figure 4. Modifying inputted linguistic terms to equivalent fuzzy numbers.](image)

| Equivalent fuzzy number | Linguistic variable |
|-------------------------|--------------------|
| ID | NGA | NDC | EC | SNPd |
| (1,1,3) | low | low | low | low | low |
| (1,3,5) | average | average | average | average | average |
| (3,5,5) | high | high | high | high | high |

**Table 6.** The entered linguistic terms and their equivalent fuzzy numbers.

| Linguistic variable | Product development | Market development | Market penetration | Symbol | Equivalent fuzzy numbers |
|---------------------|---------------------|---------------------|--------------------|--------|--------------------------|
| Diversification     |                     |                     |                    |        |                          |
| completely unfit    | completely unfit     | completely unfit     | completely unfit    | Cu     | (1,2,2)                  |
| unfit               | unfit               | unfit               | Unfit              | Uf     | (1,2,3)                  |
| rather fit          | rather fit          | rather fit          | rather fit         | Rf     | (2,3,4)                  |
| fit                 | fit                 | fit                 | Fit                | Fi     | (3,4,5)                  |
| completely fit      | completely fit      | completely fit      | completely fit     | Cf     | (4,5,5)                  |

**Table 7.** Outputted linguistic terms and their equivalent fuzzy numbers.
if (increasing demand for products is low), (new geographic areas are low), (distribution channels are low), (enough capital is low) and (new product development success is average), then (market penetration strategy is quite unfit), (market development strategy is quite unfit), (diversification strategy is quite unfit) and (product development strategy is quite unfit).

The diagrams in Supplementary Figures S1 and S2 show the output behavior of the market-product strategy selection system related to various inputs. They were developed based on these rules.

Figure S1 shows that if other inputs are constant, the possibility of selecting the new product development strategy can increase by increasing the score of success for new product development and demand for product which is consistent with what is reported in the literature. When we look at the market-product strategy matrix, the best strategy is new product development if the market is an available market and the product is a new product. Furthermore, Figure S2 shows that the possibility of selection of the diversification strategy increases by increasing the score of success of new product development and new distribution channels when the other inputs are held constant. After determining the fuzzy inference system inputs and putting them together, a questionnaire that is based on Ansoff’s work (1957) was designed. The inputs, i.e. factors that affect the selection of market penetration strategies, developing the market and diversifying the measures, along with predicted score for new product development success were entered into the inference system and market-product strategy was determined for every company.

4. Results

4.1 Predicting success of new product development efforts

The results of the trained and tested data are shown in Table 8. This data indicates that the best performance of the network occurs when functions with Gaussian membership with two membership functions for each entry are used. The results of regression for Gaussian membership function with two membership functions for each entry are shown in Supplementary Figure S3. The amounts of error of the trained data of the model are shown in Supplementary Figure S4.

Upper part of the Figure S4 indicates the compatibility of the system output with the value of the system target for the training data representing the proper performance of ANFIS in this part. The number of training samples and the value of the output and input, which were as a five-scaled Likert Spectrum, are illustrated in the horizontal and vertical part of the graph respectively. In the bottom part of the graph, the error value, mean squared error and histogram of the errors are shown.

| The type of membership function | Data type | \( R^2 \) | RMSE | MSE  |
|--------------------------------|-----------|-----------|------|------|
| Gaussian                       | Train     | 1.0000    | 0.0000| 0.0000|
|                                | Test      | 0.3823    | 1.0608| 1.1253|
| Triangular                     | Train     | 1.0000    | 0.0001| 0.0000|
|                                | Test      | 0.1520    | 1.5970| 2.5503|
| Trapezoidal                    | Train     | 1.0000    | 0.0000| 0.0000|
|                                | Test      | 0.1477    | 1.1637| 1.3541|
| Bell-shaped                    | Train     | 1.0000    | 0.0000| 0.0000|
|                                | Test      | 0.2074    | 1.1214| 1.2575|
| Foot shaped                    | Train     | 1.0000    | 0.0000| 0.0000|
|                                | Test      | 0.0083    | 1.5004| 2.2512|
Later on, when the results obtained from the adaptive neural-fuzzy network showed that Gaussian functions performed better than the others, a number of Gaussian membership functions were evaluated with various performance metrics in order to select the best one. This was done with three, four and five membership functions in each entry and the results are shown in Table 9.

The results shown in Table 9 show that the results of neural-fuzzy network were weakened by increasing the number of membership functions. Finally, the results of various performance metrics and evaluation of their performance based on various indicators showed that a network with Gaussian membership functions and two functions in each entry is the best adaptive neural-fuzzy network for predicting success of new product development efforts. In the next step, the results of this network for predicting new product development success are used as one of the fuzzy inference system inputs.

4.2 Selecting the market-product strategy

Inputs and outputs were initially selected in order to select a product-market strategy as stated above. The results of the judgment to determine the inputs of the system (factors that affect the selection of any market-product strategy of Ansoff) are shown in Table 10.

According to the calculated weights in Table 10 for every factor that affects selection of the market-product strategy, three factors of increasing demand for goods (ID), new geographical areas (NGA), and enough capital (EC) with high priorities and the factor of new distribution channels (NDC) based on its weight and importance compared with other factors were selected as factors that affect the selection of the market-product strategy according to the decision team and expert opinion. These four factors were applied as fuzzy inference system entries. In addition to these, the prediction score of the new product development success (SNPD) was added from the last section (ANFIS output) to the four previous variables. Besides, the market penetration strategy (MP), the market development strategy (MD), the product development strategy (PD) and the diversification strategy (DI) were assigned as fuzzy inference systems outputs. The Mamdani inference method was used for deducing the rules. The variables of the study as a system are shown in Supplementary Figure S5.

| The number of membership function | Date type | \( R^2 \) | RMSE | MSE  |
|-----------------------------------|-----------|----------|------|------|
| 3                                 | Train     | 1.0000   | 0.0000 | 0.0000 |
|                                  | Test      | 0.3135   | 1.4274 | 2.0374 |
| 4                                 | Train     | 1.0000   | 0.0001 | 0.0000 |
|                                  | Test      | 0.2632   | 1.5314 | 2.3451 |
| 5                                 | Train     | 1.0000   | 0.0000 | 0.0000 |
|                                  | Test      | 0.2474   | 1.5421 | 2.3782 |

| Table 10. Prioritizing every factor that affects new product development. |
|-------------------------------|---------------------------------|-------------------------------|
| Diversification strategy      | The market development strategy | The market penetration strategy |
| weight | factor | weight | factor | weight | Factor |
| 0.076  | DI1    | 0.204  | MD1    | 0.661  | MP1    |
| 0.094  | DI2    | 0.104  | MD2    | 0.078  | MP2    |
| 0.610  | DI3    | 0.502  | MD3    | 0.112  | MP3    |
| 0.085  | DI4    | 0.093  | MD4    | 0.149  | MP4    |
| 0.134  | DI5    | 0.098  | MD5    | –      | –      |
After determining the inputs and outputs of the Fuzzy Inference System explained above, the rules were codified by an expert team and were entered into the Fuzzy Inference System. At this stage, the Fuzzy Inference System was ready and the market-product strategy could be selected by using it.

Since 25 companies were studied as test companies among all food and beverage companies under study, market-product strategy for the 25 companies was determined and membership levels were calculated with the designed system after designing the Fuzzy Inference System. The required inputs were calculated by experts’ judgment and then they were entered into the system. The score of four inputs out of five ones, i.e. increasing demands for production, new geographical regions, new distribution channels, adequate capital and new product development success, were determined by experts’ judgment and the score for success of new product development was calculated by the Fuzzy Inference System’s output. The value of each entry was entered into the designed fuzzy inference system after it was calculated. Then, the strategies for each of the 25 companies were extracted along with their membership levels.

An example strategy that was developed for the companies with the designed system is shown in Table 11. Here, the level of the membership for each strategy of Ansoff matrix is calculated based on which is showed in Figure 2. In other words, the output of Fuzzy Inference System is changed to definite numbers and the level of the membership for each one is obtained based on the membership function.

### Table 11. The developed strategy for sample companies of the research test.

| Company | membership levels and linguistic terms | Strategy |
|---------|----------------------------------------|----------|
|         |                                        | Market penetration | Market development | Product development | Diversification |
| 1       | Linguistic variable | Uf | Rf | Rf | Fi | Uf | Rf | Uf | Rf |
|         | Membership levels | 0.84 | 0.16 | 0.76 | 0.24 | 0.11 | 0.89 | 0.04 | 0.96 |
| 2       | Linguistic variable | Fi | Rf | Fi | Cf | Fi | Rf | Fi | Cf |
|         | Membership levels | 0.73 | 0.27 | 0.80 | 0.20 | 0.73 | 0.27 | 0.80 | 0.20 |
| 3       | Linguistic variable | Uf | Rf | Uf | Rf | Uf | Rf |
|         | Membership levels | 0.42 | 0.58 | 0.35 | 0.65 | 0.07 | 0.93 | 0.42 | 0.58 |

... (Table continues with additional rows for companies 4 to 25)
5. Discussion and conclusions

The rate of failure of new product development efforts is high in this industry. Furthermore, companies that are active in this industry pay a high cost for their attempts toward new product development. In fact, this paper was structured based on the following question: “what tools and methods can help food industry managers to prevent the heavy costs and waste of resources in new product development projects which are largely facing failure?” Can alternative strategies be offered to these managers? Perhaps the most important achievement of this research in this respect is to code and develop an artificial intelligence system and decision-making help desk to select the appropriate growth strategies for companies in the food industry to enable more competition. The introduced model in this paper can be offered as a software tool for food industry managers to enable them to become informed about conditions for success of new product development and receive an appropriate strategy for growth only by entering data into the software program. Therefore, a combined system is introduced in this study and we tried to use it to predict new product development by applying the factors that are important at first.

In conclusion, the framework presented in this study can be considered as a decision support system for managers, businessmen and policymakers. The primary system for predicting success of new product development efforts allows the managers of the food industry to carefully assess the possibility of success of these efforts and use alternative strategies for growth in case of need prior to actual engagement in developing a new product that entails payment of high costs. Furthermore, in the second system in which one of the inputs was predicting success of development of the new product, various market-product strategies have been introduced for the growth of the company. This feature can be used by managers of the food industry in order to make decisions about the selection of the right strategy.

According to the introduced model, this paper offers the way of the selecting the alternative strategies of the new product development. Besides, an appropriate tool is suggested based on artificial intelligent as a backup system.

Newer research approaches such as artificial intelligence systems can be seen in this context. The only research study on this subject which used ANFIS is the study done by Ho and Tsai (2011). With the development of numerous applications in the field of artificial intelligence, they are easy to use for anyone with a basic knowledge of artificial intelligence systems. It should be noted that market conditions force the companies to develop new products. Naturally, this causes many managers of the food industry to consider the development of new products as their only way of staying in the competitive market. However, these managers can maintain their competitive ability by adopting alternative strategies. Moreover, by using artificial intelligence there will be more credible systems to support decisions in these industries. In this study, a model was presented to enable managers to choose the strategy of new product development plus new product development effort, and successfully carry out the assessment of the situation.

Perhaps the most important limitation of this study was the need to draw up rules based on expert judgment. FIS can be designed either from expert knowledge or from data. For complex systems, FIS based on expert knowledge alone might suffer from a loss of accuracy (Guillaume, 2001:426). Moreover, in this study, we proposed to develop the next team rules fuzzy inference system of the data-driven approach rather than using expert judgment. At the end, we recommend other researchers to use other methods of artificial intelligence such as artificial neural networks to predict success of new product development and select proper market product strategies and compare the results with the results of this research study. It is also recommended that future researchers study the tools for enhancing success of new product development and assist the managers of the food industry to succeed in carrying out new product development projects. Furthermore, in this research, retail relations in the market issues of the new product and the other barriers related to retail behavior, optimization the shelf space, and disproportionate market power were not evaluated due to the use of one theory in explaining the influencing factors on the success of the new product development.
Accordingly, future researchers are recommended to incorporate these relationships as a construct of retail relationships into their models to predict new product development.

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Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2017.0033.

Figure S1. Selecting the strategy of diversification by increasing the score of success of new product development and new products demand.

Figure S2. Selecting the strategy of diversification by increasing the score of success of new product development and new distribution channels.

Figure S3. The results for ANFIS with Gaussian membership functions and two functions for each entry.

Figure S4. The results for trained data of the neural-fuzzy network with Gaussian membership functions.

Figure S5. The Fuzzy Inference System designed in MATLAB for selecting market-product strategies.

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