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Novel Approach for Assessing the factors affecting New Product Development

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ABSTRACT

In business and engineering, new product development (NPD) is the term to describe the complete process of bringing the new product or service to the market. Business firms spend large sums of money on new product development due to many important reasons. This study is aimed to propose an approach to evaluate the factors affecting new product development in the manufacturing sector in Iran. In this regard, the BWANP method has been used. BNP is a vector-based method, which requires fewer comparisons, compared to the ANP matrix-based method. The proposed approach requires fewer comparison data, which results in creating more consistent comparisons, and obtaining more reliable results. In addition, this method can be easily used by experts. Results showed that some factors including Behavioral-cultural factors, Organizational Factors, and Environmental factors are the most important factors among the factors affecting NPD.

1. Introduction

The new product is a product bearing a new brand name, or a newly introduced item or line extension; occasionally used loosely to refer to an improved product an existing brand, or new size. In business and engineering, new product development (NPD) is the term to describe the complete process of bringing the new product or service to the market. This description begins with the identification of an opportunity in the market and comes to an end with the successful launch of the product. An NPD project connects many activities, such as classifying the requirements, developing and testing a product concept, fully defining and developing the product, sourcing for suppliers involved, planning manufacturing processes and supply chain, and designing the marketing programs. Business firms spend large sums of money on new product development due to many important reasons. The reason for new product development is the most frequently cited by top business executives are corporate growth, diversification, and the quest for a competitive edge over rival business firms. There is another specific reason for a firm to develop new products: exploiting new opportunities. The demand

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for certain product attributes can suddenly become so intense that a firm is well-advised to create and introduce a new marketplace for the new products to exploit this new opportunity and meet the strong customer demand. Product development is potentially very important for business development. Along with other forms of development such as market development, product positioning development, and supply development, product development can contribute to the attainment of key business objectives. One of the most important objectives can be contributed to by organic product development, it is rarely explained how this can be made to occur [8].

One of the most important branches of decision theory is multi-criteria decision making (MCDM). These methods face two types of problems of continuous and discrete solution space. The method MADM is used to solve discrete problems and the method multi-objective decision making (MODM) is used for other problems. For various reasons, the use of some MCDM methods causes inconsistencies in the data. For this reason, in this research, the Best-Worst Analytic network process (BWANP) method is presented, in which identifying the best and worst criteria, will help decision-makers to present their opinions in fewer questions and consequently create lower incompatibility rates.

In this paper, the BWANP method has been used which is a vector-based method, which requires fewer comparisons, compared to the ANP matrix-based method. Like the ANP, BWANP first calculates Eigenvectors and then, a super-matrix is formed, but, the difference between the two methods is how to calculate eigenvectors. Therefore, to calculate the eigenvector, first, the best (most important) and worst (least important) criterion should be determined and then, the preference of the best criterion over all the other criteria$\widetilde{\alpha_{BJ}}$ and also the preference of all the other criteria over the worst criterion$\widetilde{\alpha_{JW}}$ are determined and the criteria's weight is calculated according to the BWM method. In the other words, all elements of AHP pairwise comparisons matrix are not needed to calculate the eigenvector , and only one row and one column of it are needed, namely the row and column representing $\widetilde{\alpha_{BJ}}$ and $\widetilde{\alpha_{JW}}$. In F-BWANP, only this row and column is calculated. After determining $\widetilde{\alpha_{BJ}}$ and $\widetilde{\alpha_{JW}}$ the model is formulated in form of a linear programming problem and solved. In this approach, the comparisons are considerably reduced [19].

Decision-making methods usually end up asking a lot of questions from decision-makers, which can cause difficulties and inconsistencies in the data. Using the right models by reducing the volume of questions and including tips in the questions (e.g., providing the best and worst criteria) will greatly reduce inconsistencies. There are many benefits to using this method, some of which are as follows:

- By identifying the best and the worst criteria (or the alternatives) before conducting the pairwise comparisons among the criteria (or the alternatives), the DM already has a clear understanding of the range of evaluation which could lead to more reliable pairwise comparisons. This, in turn, implies more consistent pairwise comparisons, which has been shown in the original BWANP study.
- The use of two pairwise comparisons vectors formed based on two opposite references (best and worst) in a single optimization model could mitigate possible anchoring bias that the DM might have during the process of conducting pairwise comparisons.
- In pairwise comparison-based methods, we either have methods for which we use a single vector (e.g., Swing and SMART family) or a full matrix (e.g., AHP). Although using one vector for the input data makes the method very data (and time)-efficient, the main weakness of methods based on only one vector is that the consistency of the provided pairwise comparisons cannot be checked. On the other hand, although using a full matrix provides the possibility of checking the consistency of the provided pairwise comparisons, methods which are based on a full pairwise comparison matrix are not data (and time)-efficient. Asking too many questions from the DM, which occurs in the case of a full matrix, might even contribute to the confusion and inconsistency of the DM. BNP stands in the middle. That is to say, it is the most data (and time)-an efficient method which could, at the same time, provide the possibility of checking the consistency of the provided pairwise comparisons.

BWANP, in the not-fully consistent cases with more than three criteria (or alternatives), might bring about

multiple optimal solutions. This is a reflection of the inconsistency which exists in the provided data. Having multiple optimal solutions (compared to a unique solution) brings more flexibility to the cases where there are multiple DMs involved. This means that in the context of group decision-making, having multiple optimal solutions (for all or some DMs) could result in a higher chance (compared to the case that each DM has a unique solution) for a compromise solution to coincide (or at least be very close) to one of the optimal solutions. Although having multiple optimal weights is advantageous in some cases, especially in group decision-making problems, where debating plays a central role, in other cases, having a unique solution is preferred. The linear BWANP model provides a unique solution that this research uses from it.

The paper proceeds as follows. The next section reviews the research related to the previous research topic. Section 3 gives basic definitions of BWANP method. Section 4 formulates the model of BWANP. Finally, Section 5 presents the conclusion with future study.

2. Literature Review

NPD is a method of bringing a new product to the marketplace. This involves designing, growing, developing, and launching a new service or product [35].

New product development in particular has been characterized as a knowledge-based activity. It has long been known that knowledge is normally widely dispersed, but more recently the importance of using external sources of knowledge in companies' innovation processes has been increasingly highlighted in innovation management.

New product development is an inter-linked sequence of information processing tasks where knowledge of customer needs is translated into final product design [23]. It is one of the most powerful but difficult activities in business [14]. Success in new product development is a critical management issue, particularly in technology-driven firms. Managers of new products have little guidance on how to improve or redirect their organization's external orientation towards their product target market. The NPD process differs from industry to industry and from firm to firm. Indeed, it should be adapted to each firm to meet specific company resources and needs [7]. Ramaseshan et al [26], mentioned that determinants of new product performance are interrelated and that the new product development process itself is central, namely the stages of initiation and implementation. The stage of initiation appears to be more important and it is strengthened by the factors such as customer orientation, cross-functional integration, and proficiency to the new product team. The study by Wei and Morgan provided three implications of theoretical knowledge concerning a firm's new product performance [36]. Firstly, the important role played by supportiveness of organizational climate in determining a firm's market orientation is identified and supported empirically, which in turn explains significant variance in the success of the new product in the Chinese firms. Secondly, the study's fieldwork interviews and its empirical result indicated the importance of the cultural contexts of the firm in explaining how the firm's engagement in processing market information, enables them to achieve superior performance for new products. Thirdly, their findings indicate that organizational climate is important in determining new product performance through its effect on a firm's market orientation behaviors. The process of New Product Development consists of several key stages, including identifying customer requirements, developing a product concept, generating a detailed design, testing, and product commercialization. At each of these stages, several functional areas are involved– R&D, marketing, and manufacturing, among others–and effective communication and collaboration are fundamental to the development of successful products. The most common way to manage the different stages and functions involved in NPD is the universal Stage-Gate' methodology developed by Cooper and Kleinschmidt [16]. The new product development literature stresses also the importance of a clear management process. Researchers have noted that all functional areas should be involved in NPD [33]. According to Cooper [17], successful new product development needs a robust process, in which the responsibilities of members of the cross-functional team are clearly defined. This team requires good leadership [5]. and good open communications [28].

Analytic Network Process can be applied in many areas [30, 34, 29]. ANP is further used in areas including,

Decision making, Evaluation, selection QFD, Planning and Development, Priority and Ranking, and Forecasting. Decision-making is the mental process of choosing from a set of alternatives. Every decision-making process produces an outcome that might be an action, a recommendation, or an opinion. Since doing nothing or remaining neutral is usually among the set of options one chooses from, selecting that course is also making a decision. There are much research works in this area and we address some of them [21]. In their work [12]. used the ANP method for generating a location selection model to determine the best location out of a choice of three alternatives for a biotech park in Taiwan. They suggested two ANP models that consider the environmental issues, and then, the two methods were combined to select the best plan out of the three ones. Cheng [2], used the ANP and AHP to select the best shopping mall location.

To prioritize the design requirements as a part of the house of quality ANP approach was used. Pal et al [25] proposed an integrated method using ANP and QFD. This approach was used to determine and prioritize the engineering needs of a cast part to select a suitable, rapid prototype-based route to tool manufacturing.

Some researchers have sought to combine this method with other methods for better use of ANP, resulting in ISM-ANP and D-ANP methods that try to improve the relations matrix in ANP [10], or GP-ANP that attempts to obtain better results from ANP [17].

In this paper, the BWANP method is provided, through which, while achieving more relatable results, the pair-wise comparisons would be facilitated and reduced.

So far, various researches have been done about identifying the factors which are influencing the success of the new product which the most important ones are mentioned in Table 1:

Table 1. Selected research on the factors affecting NPD

Authors	Success measure
[18]	• Top Management Commitment • Presence of Clear Goals & Milestone Measurement • User/Customer Involvement • Involvement of Cross-Functional Teams • Placement of Structured NPD Process • Talented Team Members with Relevant Experience to NPD Process & Activities • Establishment of An Entrepreneurial Culture • Effective Communication Amongst Team Members & With Management • Alignment of NPD Process Activities with Strategy • Focusing on Innovation & Out-Of-The-Box Ideas • Availability of Financial Requirements • NDP Process Speed
[22]	• Supplier integration • Strategic alliances • Client integration • Sustainability • Design • Portfolio management • Management tools • Innovation supply • Information technology

	• Marketing • Management flexibility • Enterprise network • Cost forecast • Open innovation • Knowledge management • Reverse engineering
[20]	• Senior management involvement • Early customer involvement • External collaboration beyond customers • Alignment between NPD and strategy • Adequate degree of formalization • Cooperation among functions and departments • Creative organizational culture • Project management capabilities
[9]	• Strategy • Commercial station • Marker research • Company culture • Project climate • Performance • NPD process
[24]	• Collaborative product development • ICT • Concurrent engineering • Quality function deployment • Continuous improvement
[31]	• NPD strategy • Company or innovation culture, people, and project climate • Front end innovation practices • Portfolio management • NPD process • Metrics and performance evaluation

3. BWANP method

ANP uses the pair-wise comparisons of AHP to calculate eigenvectors, resulting in a significant increase in pair-wise comparisons [30]. BWANP has eliminated the problem and uses the BWM comparisons [27]. to calculate eigenvectors that need fewer comparison data and leads to more consistent comparisons, which means that BWANP gives more reliable answers [2,6].

Because it requires fewer comparison data

Steps of BWANP:

1 The decision problem is decomposed into its decision elements and structured into a hierarchy that includes an overall goal, criteria, sub-criteria, and alternatives, with the number of levels varying depending on the complexity of the problem and the number of factors to be considered [3].

2 Using pair-wise comparisons:

a Determine the best (most important) criterion and the preference of the best criterion over each of the other criteria using a number between 1 and 9. The resulting Best-to-Other's vector would be:

$$A_B = (a_{B1}. a_{B2}. \ldots . a_{Bn}) \quad (1)$$

b Determine the worst (least important) criterion and the preference of each of the other criteria over the worst criterion using a number between 1 and 9. The resulting Others-to-Worst vector would be:

$$A_W = (a_{1W}. a_{2W}. \ldots . a_{nW})^T \quad (2)$$

3. Determine the optimal weights.

$$w_j \geq 0 \,. for\ all\ \ j \quad (3)$$

By solving the above model, optimal values of $(w_1^*. w_2^* \ldots . w_n^*)$ and $\tilde{\xi}$ are calculated so that the bigger value of $\tilde{\xi}$ represents a higher consistency. Since the consistency ratio can be calculated using the consistency index of Table 2 and Equation (4), as consistency ratio are closer to zero, results are more consistent [3].

$$Consistency\ Ratio = \frac{\xi}{Consistency\ Index} \quad (4)$$

Table 2. Consistency index (CI) table

a_{BW}	1	2	3	4	5	6	7	8	9
consistency index	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

At the end of step 3, W22 is calculated which is a part of the initial super-matrix. To complete the other parts of the initial super-matrix such as W21, W23, and W32, steps 1 to 3 are exactly done corresponding to each section. After calculating all the W_{ij}'s required for the initial super-matrix, the algorithm enters step 4 and the final weights are determined [1].

4 Form the super-matrix. After forming the super-matrix, the weighted super-matrix is derived by transforming all column sums to unity exactly. Next, we raise the weighted super-matrix to limit powers such as Eq. (5) to get the global priority vectors or so-called weights:

$$\mathbf{lim}_{\boldsymbol{k\to\infty}}\, \boldsymbol{W_w^k} \quad (5)$$

In addition, if the super-matrix has the effect of cyclicity, the limiting super-matrix is not the only one. There are two or more limiting super-matrices in this situation and the Cesaro sum would be calculated to get the priority. The Cesaro sum is formulated as:

$$\lim_{k\to\infty}(\tfrac{1}{N}) \sum_{r=1}^{N} W_r^k \quad (6)$$

To calculate the average effect of the limiting super-matrix (i.e., the average priority weights) where Wr denotes the rth limiting super-matrix. Otherwise, the super-matrix would be raised to large powers to get the priority weights [6].

4. Data analysis

To select the factors affecting the success of new product development, many factors obtained from the review of theoretical foundations were entered into a screening questionnaire, and experts were asked to answer the questions. Finally, after analyzing the data of the screening questionnaire, 12 key factors were confirmed and

selected (Table 2).

Table 3. Key factors affecting NPD

C1	strategic management
C2	Marketing management
C3	Communications
C4	Technology management
C5	Organizational factors
C6	Behavioral-cultural factors
C7	Environmental factors
C8	Financial factors
C9	Management factors
C10	Risk factors
C11	Research and development budget
C12	Human resources performance

In the following, calculations of BWANP approach are provided.

Calculation of matrix W21:

The matrix W21 is the eigenvector, representing the importance of criteria with regard to the goal. According to the experts, the most important criterion is C8 and the least important criterion is C11 that their comparison with other criteria is provided in Table 4. The calculations related to determining the Weights of matrix W21 are provided in Table 5.

Table 4. Pair-wise comparisons of criteria with the best and the worst criterion

	C1	**C2**	**C3**	**C4**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
BEST:C5	4	2	5	3	3	6	4	7	8	9	5
	C1	**C2**	**C4**	**C5**	**C6**	**C7**	**C9**	**C10**	**C11**	**C12**	
WORST:C3	6	8	7	6	7	4	3	2	5	5	

Table 5. Modeling and solving the model

$MIN\ \xi$	ξ	0.053	for all experts	
$\lvert C8\text{-}4*C1 \rvert \le \xi$	C1	0.074	C1	0.075
$\lvert C8\text{-}2*C2 \rvert \le \xi$	C2	0.147	C2	0.153
$\lvert C8\text{-}5*C3 \rvert \le \xi$	C3	0.059	C3	0.059
$\lvert C8\text{-}3*C4 \rvert \le \xi$	C4	0.098	C4	0.107
$\lvert C8\text{-}4*C5 \rvert \le \xi$	C5	0.074	C5	0.075
⋮	C6	0.098	C6	0.102
$\lvert C6\text{-}7*C11 \rvert \le \xi$	C7	0.049	C7	0.047
$\lvert C7\text{-}4*C11 \rvert \le \xi$	C8	0.242	C8	0.234
$\lvert C9\text{-}3*C11 \rvert \le \xi$	C9	0.042	C9	0.040
$\lvert C6\text{-}7*C11 \rvert \le \xi$	C7	0.049	C7	0.047
$\lvert C7\text{-}4*C11 \rvert \le \xi$	C8	0.242	C8	0.234
$\sum Cj=1\ ,\ Cj \ge 0$	C12	0.059	C12	0.058

Calculation of matrix W22

This matrix compares the criteria based on each criterion. In this step, in order to determine the internal dependency of criteria, ISM method is used. Calculations related to the criteria's weights are based on C1 is shown in Tables 6 and 7. The operation is also performed for the other criteria, and its final result can be seen in Table 8.

Table 6. Pair-wise comparisons of criteria with the best and the worst criteria based on C1

	C2	**C4**	**C5**	**C9**	**C10**	**C12**
BEST:C3	4	2	3	6	7	4
	C3	**C4**	**C5**	**C9**	**C10**	
WORST: C12	4	6	5	2	4	

Table 7. Modeling and solving the Model-Eigenvector based on C1

MIN ξ	ξ	0.064	for all experts	
$\lvert C2-4*C3 \rvert \le \xi$	C2	0.345	C2	0.334
$\lvert C2-2*C4 \rvert \le \xi$	C3	0.102	C3	0.102
$\lvert C2-3*C5 \rvert \le \xi$	C4	0.205	C4	0.212
⋮	C5	0.136	C5	0.139
$\lvert C5-5*C10 \rvert \le \xi$	C9	0.068	C9	0.067
$\lvert C9-2*C10 \rvert \le \xi$	C10	0.040	C10	0.041
$\lvert C12-4*C10 \rvert \le \xi$	C12	0.102	C12	0.102
$\sum Cj=1 , Cj \ge 0$				

Table 8. Results of calculating the matrix W22

	C1	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C11**	**C12**
C1	0	0.102	0.098	0.089	0.077	0.122	0.094	0	0.096
C2	0.334	0.211	0.203	0.185	0.159	0.293	0.194	0	0.199
C3	0.102	0.081	0.078	0.071	0.061	0.090	0.074	0.791	0.076
C4	0.212	0	0.134	0.122	0.105	0.186	0.129	0	0.131
C5	0.139638	0.102	0	0.089	0.077	0.122	0.094	0	0.096
C6	0	0	0	0	0.105	0	0	0	0
C7	0	0	0	0	0	0	0	0	0
C8	0	0.329	0.318	0.289	0.246	0	0.305	0	0.311
C9	0.067	0.057	0.055	0.050	0.043	0.059	0	0	0.054
C10	0.040	0.034	0.032	0.029	0.037	0.035	0.031	0.208	0.032
C11	0	0	0	0	0.022	0	0	0	0
C12	0.102	0.081	0.078	0.071	0.061	0.090	0.074	0	0

Finally, the weights were obtained and the Super-matrix was completed. The limiting super-matrix can be seen in Table 9.

Table 9. Limiting super matrix

	G	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
G	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
C2	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
C3	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
C4	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
C5	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141	0.141
C6	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172	0.172
C7	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
C8	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
C9	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
C10	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
C11	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
C12	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

5. Conclusions and suggestions

New products are essential to the survival and long-term growth of a firm. Business firms spend large sums of money on new product development due to many important reasons.

In [4], 29 factors such as Tools Methods and fans, connections, Modeling, Team building, supply chain, Value creation factors, Commercialization factors, Supporting factors, Behavioral factors, Organizational factors, cultural factors, Technical factors, Financial factors, Environmental factors, Management factors, Customer factors, Attitudinal factors, Information Technology, Strategic Management, Marketing Management, Project Management, knowledge management, risk management, Quality management, Human resources management, Product Features, Process features and Development resources have been identified which some of these factors are also mentioned in this research.

Also, in [32] 26 factors Investment risk, Technical ability, Customer satisfaction, Product compliance with customer demand, Customer acceptance, Management support, Product development planning, Reward ideas, Supporting creativity, Creativity, Employee competence, Education, Research and development investment, profit, Advertising, Predict customer needs, Extent of the distribution system, Raw material, Quality, Designing, Competitiveness, Product charm, Supplier risk, External communication, Market share and Price have been identified such as that some of these factors are also mentioned in this study. He showed that the mentioned cases have had a great impact on the development of the new product, which is convergent with our research.

Table 1 also shows the factors that have been extracted from previous research, which are affecting the new product development process.

Among the 12 factors which were investigated in this study, several factors are more important such as cultural factors, Organizational factors, Environmental factors. These factors had a key role in the progress of the new product development process. This study is aimed to propose a model for assessing the factors affecting new product development in the manufacturing sector in Iran. As the final assessment made in this study suggests, some factors including Behavioral-cultural factors, Organizational factors, and environmental factors are the most important factors among the factors affecting NPD. BWANP is a vector-based method that requires fewer comparisons compared to matrix-based MCDM methods such as AHP. For BWANP, we only need to have $2n-3$ comparisons while, for instance, for AHP, $\frac{n(n-1)}{2}$ comparisons are needed. Azizi (2020) also pointed to this reduction in the rate of pairwise comparisons and its effect on the rate of incompatibility in her research through similar methods.

In the BWANP method, it has been observed that integers have been used and other decimal numbers have

not been used, which will reduce errors by decision-makers.

According to the research findings, to succeed in new product development projects, it is necessary to pay attention to cultural factors, organizational factors, and environmental factors as infrastructure and key variables. The method of data analysis is also very important, which will affect the degree of accuracy. To this end, suggestions have been made to reduce the failure rate of new product development projects:

- Supervise the implementation of intellectual property laws to reduce counterfeiting activities from innovations introduced to the market
- Assign a dominant, influential, and strong manager to a new product development project to create commitment among different resources
- The institutionalizing organizational culture encourages innovation and supports creative change and pays attention to transformational leadership style
- Improve product development planning: One of the policies that can increase the success of product development can be the policy of increasing and improving product development planning.
- In this study, it was shown that using methods with fewer comparisons will reduce the error rate. It seems that the use of methods such as Bayesian or decision tree can also have a positive effect on the analysis. To understand the impact of this type of analysis, which is excluded from MCDM analysis, implementations should be made and the results should be compared with studies similar to this study.
- Always using different methods of analysis together can improve the analysis. For this purpose, you can first perform an initial screening on this data to enter the data into the analysis, which can be done in different ways, and after entering this data into the analysis, you can see the improvement.
- Modified fuzzy victor method can also be used to find the best and worst criteria.

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