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Original Article

Choosing Technology by Using a Combined ANP and DEMATEL in Cellulose Industry (A Case Study: Tissue Paper Manufacturing Technologies)

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ABSTRACT

Choosing a proper technology is one of the most important challenges in establishment and expanding of an industrial unit. In the cellulose industry, various technologies can be used and each of them includes advantages and disadvantages. In this case, technology selection is very critical, therefore the cellulose industry is considered as the case study in this research. The ANP method is one of the latest amongst the multi-criteria decision making methods and the technology selection is also a multi-criteria decision making challenge. In the first step of the research, the expert's opinions are used to detect the alternatives. In the next stage, a model is chosen from the previous. In order to determine the level of dependency of each criterion on the considered industry, criteria are sifted by Shanon Entropy technique. In the next step, another questionnaire is created by means of the current DEMATEL technique, in order to detect the expert's opinion about interior dependency of different. The last questionnaires are developed for the pairwise comparison between model elements and for comparing the alternatives. Finally, the resulted data are imported to Super Decision software in order to evaluate the alternatives and consequently, the most proper technology is selected.

Keywords: Analytic Network Process, Shanon Entropy Technique, DEMATEL, Super Decision Software.

Introduction

In management of a company, technology selection is one of the most demanding areas to make decisions about (Torkkeli and Tuominon, 2002). Yu, Hsu, and Chen (1998) stated that a company has to select and invest in a technology field with comparative advantages from different technology–alternatives based on multiple factors and criteria within the environment.

To be competitive and to grantee growth and improvement, technology based enterprises depend on the innovating technological resources and productive use of new technologies (Mcnamara and Baden –fuller, 1999). To remain competitive and innovative, professional technological planning and strategy is highly demanding. Enterprises, firms, and countries could be supported by accurate selection of key technologies in this competitive environment (Clark, 1989; Lee and Song 2007; Morone, 1989; Torkkeli and Tuominem, 2002).

Khalil (2000) believes that selecting and supporting main innovating and new technologies will help countries to establish their advantages in international market. Technology selection is a multiple criterion decision making challenge as Lamb and Gregory (1997) puts it. Consideration of various aspects such as potential cost, expenses, benefit and risks is highly essential for decision makers.

In addition, cost, benefit, and risks of technologies are interdependent in real world. To address this demanding decision making issues this study aims to introduce a hybrid technology selection process integrating the Shannon Entropy method, the decision making trial and evaluation laboratory (DEMATEL) technique, and the analytic network process (ANP) with navel MCDM method for the best cellulose technology selection. The Shannon Entropy method is applied to analyze the data obtained by scales related to measuring relationships between criteria and cellulose industry, through this method, the sub-criteria are sifted and the model related to cellulose industry will be developed. The DEMATEL is used for building and detecting of network relationship map (NRM) among different criterion. Furthermore, the ANP is applied to conduct the dependence and feedback among criteria and to decide the relative weight of the criteria by supermatrix. The combination of Shannon Entropy, DEMATEL technique and ANP with novel MCDM method is employed for performance of constructing a technology selection structure.

Moreover, Ronde (2003) states that the complexity of relations between technologies and economic problems accompanied by occurrence of national or organizational budget resource limitation encounter science and technology with a new challenge. In the following (section 2) related technology selections studies are reviewed. Section 3 describes the proposed technology selection processes integrating the Shannon Entropy, the DEMATEL, and the ANP in section 4 present a combined method to select a technology among technology alternatives for tissue production technology related to cellulose industry and finally section 5 provides concluding remarks.

Technology Selection

In manufacturing industries, technology is widely accepted as a key source of competitive advantage. Investing wrong alternatives, at the wrong time can waste the competitive advantages in enterprises (Torkkeli and Tuominen, 2002). Investing in emerging and innovating technology can help countries to obtain competitive advantages (Lee and Song, 2007; Yu et al., 1998). For realization of the competitive advantage, understanding specific technologies as well as the best management technology is of the highest importance (Phaal, Farrakh, and Probert, 2001).

According to Gregory (1995), management of technology is comprised of 5 generic processes which are: Identification, selection, acquisition, exploitation, and protection. Technology selection is defined as involvement of technology choices and supports and promotions (Gregory, 1995). Technology selection involves gathering information from various sources about different alternatives as well as evaluation and assessment of these alternatives. Further, Gregory (1995) distinguished identification and selection phases. According to Gregory identification is gathering alternatives while selections are action to decide on different alternatives. Dassauge, Hart, and Ramanatsoa (1992) define technology selection as identification or selection of innovative or additional technologies, which enterprises seek to. All in all, one could say technology selection is a process highly related to organizational objectives. It should be noted that identification of right technology is not an easy job, since the number of technologies is increasing and they are complicated more than before (Torkkeli and Tuominen, 2002). Moreover, rising cost of technological development, huge number of technology options and rapid diffusion of technology are different challenges which decision makers will face. (Berry and Taggart, 1994; Lei 2000, Steensma and Fairbank, 1999). For example, technology accounts on average for more than one-third of all business capital spending (Bakos, 1998). Cantwell (1992) states that difficulty in selection of appropriate technology and assessing them are due to abundance and complexity of technological options. In addition, studies showed that many companies fail to evaluate new technologies.

It is said that poor management and assessment usually result in failure of a chosen technology (Huang and Mak, 1999). Previous studied proved that careful assessment for overcoming the difficulty of technology selection is essential before introducing new technologies (Efstahiades, Tassou, Oxinos and Antoniou, 2000)

Building a Novel Hybrid MCDM Model for Tissue Production Technology Selection

To have the best tissue production technology a novel hybrid MCDM model is used to evaluate problems. Different techniques of novel hybrid MCDM models are as following:

(1) By literature review of technology selection and by consulting with some experts in this field, the primary model was constructed. (2) Some experts were surveyed by a scale on relationship between all criteria and cellulose industry. The relationships were evaluated and the data will be analyzed by Shannon Entropy. Also the DEMATEL technique helps to determine relationships and construct NRM among these criteria. (3) Composing ANP supper matrix by output from DEMATEL technique and common scales on AHP model. Finally (4) evaluation model is used to improve and select the best tissue production technology. This study proposes a technology selection process using four methods in order to present and extract their advantages. To conduct technology selection, Shannon Entropy was used to analyze the data related to also DEMATEL technique and ANP involve in the assessment of economic or industrial consideration toward a more efficient evaluation of technology alternatives.

Shannon Entropy

For data analyses obtained by questionnaires and composing a related model to cellulose industry, an innovative method was used in this study. To analysis the data Shannon Entropy technique, which is a common way for weighting to criteria, was applied. A fundamental concept in physics, social science and different systems is Shannon Entropy which indicates the measure of unpredictability of message content.

In other words, in information theory, entropy is a criterion for measuring uncertainty defined by a discrete probability distribution P_i so that this uncertainty is elaborated as following (Mahara and Yamaguchi, 2010):

$$E_j = -K\sum_{i=1}^{m} p_{ij}\ln(p_{ij}) \quad , \forall_j \qquad (1)$$

which

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \quad , j=1,2,\dots, n, \quad \forall_j \tag{2}$$

$$K = \frac{1}{\ln(m)} \tag{3}$$

Finally, by obtaining E_i related to each criterion, those criteria, which have lesser weight would be considered as unrelated and would be canceled.

DEMATEL Method

All criteria of an interdependent system are related either directly or indirectly therefore, any defect in each criterion affects all others (Tzenig, Chiang and Li 2007). The DEMATEL, originated from the Geneva Research Centre of the Battelle Memorial Institute (Fontela and Gabus, 1976; Gabus and Fontela, 1973), aims to converts the relationship between the causes and effects of criteria in a system (Huang, Shyu, and Tzeng, 2007; Lee, Kim, Cho, and Park, 2009; Lin and Tzeng, 2009; Liou, Yen, and Tzeng, 2008; Ou Yang, Leu, and Tzeng, 2009; Tzeng *et al.,* 2007; Vujanović *et al.,* 2012), The DEMATEL method is briefly described as follows:

Step 1: Calculate the initial direct-relation matrix.

Experts are asked to indicate the direct influence degree between criterion i and criterion j, as indicated by z_{ij}, using a pairwise comparison scale designated five levels, where the scores ranging from 0 to 4 represent "no influence" to "very high influence" , respectively. The initial direct-relation matrix $Z = [z_{ij}]_{l*l}$ is obtained by pairwise comparisons in terms of influences and directions between criteria, in which l denotes the number of criteria.

Step 2: Normalize the direct-relation matrix.

The normalized direct-relation matrix ***D*** is obtained through Equation. (4) and (5), in which all principal diagonal elements are equal to zero.

$$D = \lambda . Z \tag{4}$$

$$\lambda = Min[\frac{1}{\max 1 \le i \le n \sum_{j=1}^{n} |z_{ij}|}, \frac{1}{\max 1 \le i \le n \sum_{i=1}^{n} |z_{ij}|}] \tag{5}$$

Step 3: Calculate the total-relation matrix.

Once the normalized direct-relation matrix ***D*** has been obtained, the total-relation matrix ***T*** is acquired by Equation (6):

$$T = D(I - D)^{-1} \tag{6}$$

where I is the identity matrix.

Step 4: Obtain the inner dependence matrix.

In this step, the sum of each row in total-relation matrix is equal to 1 by normalization method, and then the inner dependence matrix can be acquired for ANP super-matrix in diagonal matrix (Wu, 2008; Shen, Lin & Tzeng, 2011).

The ANP

The ANP is a generalization of AHP (Saaty 1996) to overcome the problem of interdependence and feedback between criteria (Lee, Tzery, Guan, Chien, and Huang, 2009). In AHP which is one of the most widely used multiple criteria a decision making (MCDM) method, a problem is decomposed into different levels and a hierarchy is made up. In the hierarchy, each decision element is considered as an independent one. The ANP extends the AHP to solve problems with dependence and feedback and it provides more complex interrelationship among decision elements by replacing a hierarchy in the AHP with a network (Meade and Sarkis, 1999). Several studies have adopted the ANP to conduct the problem of technology selection (Erdoğmuş, Kapanoglu, and Koç, 2005; Erdoğmuş, Aras, and Koç, 2006; Kengpol and Tuominen, 2006; Lee *et al.,* 2009; Vujanović *et al.,* 2012).

DEMATEL technique is used to build the network relationship map (NRM) in order to construct supermatrix in ANP. Through this procedure, the difficulty of ANP in determining the dependence and feedback among dimensions would be overcome. Based on NRM, the ANP conduct dependence and feedback within a cluster and among different clusters. In order to form a supermatrix through pairwise comparison, the criteria in the entire system should be compared in ANP. The first step of the ANP is the comparison of the criteria in the entire system in order to form a supermatrix. Saaty (1980) recommended a nine-point scale to obtain expert`s opinions with preferences between alternatives given as equally, moderately, strongly, very strong, or extremely preferred.

The general form of the supermatrix is shown as Equation (6):

$$A = \begin{array}{c c} & \begin{array}{ccc} C_1 & C_2 & C_s \\ e_{11}\cdots e_{1t_1} & e_{21}\cdots e_{2t_2} & e_{s1}\cdots e_{st_s} \end{array} \\ \begin{array}{c c} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1t_1} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ \vdots \\ e_{2t_2} \\ \vdots \end{array} \\ C_s & \begin{array}{c} e_{s1} \\ \vdots \\ e_{st_s} \end{array} \end{array} & \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1m} \\ A_{21} & A_{22} & \cdots & A_{2m} \\ \vdots & \ddots & \vdots & A_{11} \\ A_{s1} & A_{s2} & \cdots & A_{ss} \end{bmatrix} \end{array}$$

"Within clusters, C_S, which is known as inner dependence and between clusters, which is known as outer dependence, where Cs donates the *s*th cluster, e_{st} denotes the *t*th element in the *s*th cluster, and matrix $A_{ss'}$ is the principal eigenvector of the influence of the criteria compared in the *s*th cluster to the *s'*th cluster" (Shen, et al. 2011, p.1472) in supermatrix the impact of the model relative to the complete element set, are presented.

In fact, the eigenvector solutions within the components are the actual elements that make up the columns (Ass'). The columns of a supermatrix usually sum to more than one because clusters are interdependent in order to make the supermatrix stochastic – each column of the matrix sums to unity – it must be normalized.

The final priority weights, related to element introduction, are derived by multiplying supermatrix by itself until the columns stabilize (Niemira and Saaty, 2004)

The Case of Tissue Production Technology Selection in Cellulose Industry

Since hygiene is highly important when it comes to prevention, hygienic products including tissue have prosperous market in most countries around the world.

Cellulose industry is one of the commonest industries in Iran with promising internal market. Furthermore, there are great opportunities for exporting products coming from cellulose industry to other countries. Despite all difficulties in Iran industries, cellulose industry is increasingly growing and can encourage currency and help the economy with current problems. Furthermore, by increase in Dollar value and decrease in the Rial value, appropriate opportunities have been provided for exporting more products from this industry. For this reason cellulose and tissue production industry are considered as important ones. Production technology selection in tissue production industry is quite delicate because there are a variety of alternatives, which have their own advantages and disadvantages; selection of each has different effects on production results and conditions. On the other hand, due to the simplicity of production processes in this industry and high dependency of it on the final results and conditions of production and technology of production, every industrial unit success is highly related to appropriate production technology selection. The proposed methodology is developed in a six step processes, which are shown in Figure 1 as a process flow chart and it is presented in details in the following sections.

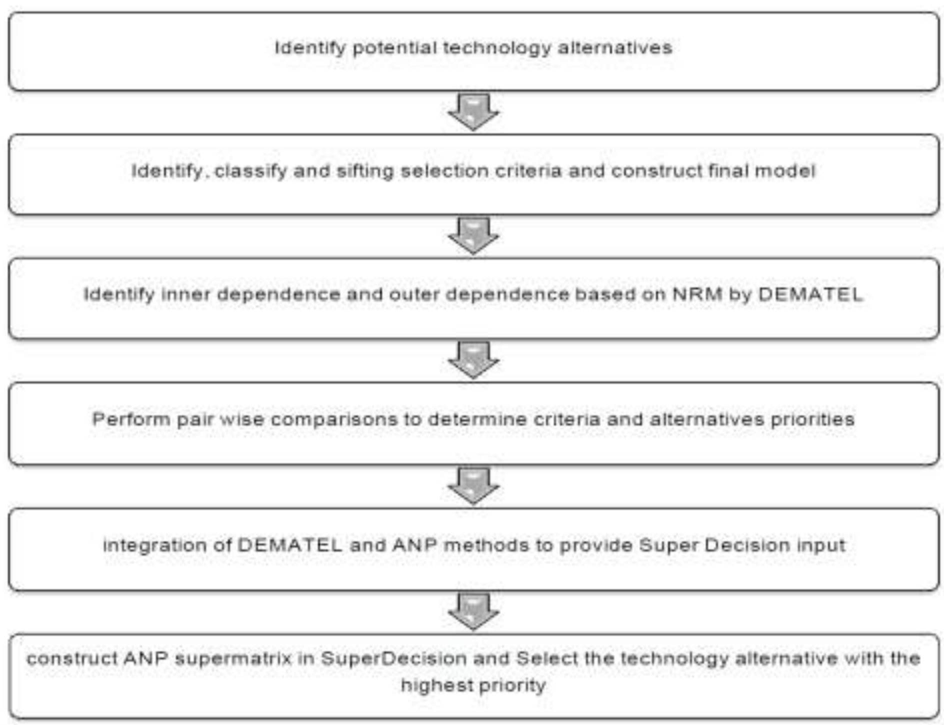

Figure 1. Process flow chart for technology selection

Identify Potential Technology Alternatives

To select technology in every industry the main challenge is selecting the most appropriate and competitive technology alternatives. This study conducted in two steps for selecting technology alternatives and overcoming theses challenging. Visiting in 20th international exhibition of detergents, hygienic, and cellulose material and related machinery which was hold on 18th -21st of May in 2013. In this exhibition features and catalogs of major producers of cellulose technology industry in Iran and other countries were identified and communicated.

There were 4 technologies with different features and facilities, having consulted with some experts, three of them were recognized by productive industries and were produced in internal production and the other one is produced by a Chinese company.

Since each of these alternatives can have different effects and specific results for this industry, selection among these technologies is highly vital. One could say these technologies are representative of all different technologies in cellulose industry. For this reason, selection among these technologies could have a general and appropriate approach toward this technology.

Identify, Classify, and Sifting Selection Criteria and Construct Final Model

Related literature is reviewed first to construct the technology selection model regarding economic or industrial prospect. Arbel and Shapira (1999) developed the selection model focusing on benefits and cost. Piipo and Tuominen (1990) emphasized that the matching of alternatives to the capabilities and strategies of companies is very important. Yap and Souder (1993) consider some factors very important and emphasized their rules. These factors are: uncertainty of commercial and technical success, funding history of technology, the source requirements to develop technology, attribution of technology to established missions and current life-cycle stage of technology.

Yu *et al.,* (1998) on the other hand, emphasized on business opportunities, present technology, strategic importance, business effect, risks and cost to obtain the technology to evaluate. (Coldrick *et al.,* 2005) focus on technological corporate, strategic factor, regularity market, financial as well as application factors of the R&D project selection. A technology selection process consists of requirements filters, adaptation, internal factors, and external factors proposed by Shehabudeen *et al.,* (2006). Huang, Chu, and Chiang (2008) emphasize the scientific and technological merit, potential benefits, project execution, and the project risk for the government-sponsored R&D project selection.

The model with mentioned literature is the results of the following studies (Arbel and Shapira, 1999; Coldrick *et al.,* 2005; Huang et al., 2008; Piipo and Tuominen, 1990; Shehabuddeen *et al.,* 2006; Shen *et al.,* 2010; Shen, Lin and Tzeng, 2011; Yap & Souder, 1993; Yu *et al.,* 1998). These criteria are introduced in Table 1 with a short description and their references.

For filtering important criteria, the Shannon Entropy method was applied. In this study ten experts of this industry all are CEOs (Chief Executive Officer) were surveyed then they evaluated collected criteria by questionnaires. In the questionnaires each criterion was defined and described, experts then were asked to identify the relationship between the criterion and cellulose industry in the forms of extremely important, important, normal, unimportant, extremely unimportant options. The amounts of entropy were obtained by considering each option value (1, 3, 5, 7, and 9). The threshold value on number of final criterion will be effective. If the threshold value be high the number of criteria will be few and if this amount be high the sifting will be meaningless. As a result, threshold value was considered entropy as 0.98. According to result obtain from criteria sifting, 7 criteria were omitted they were: advancement of technology, key of technology, proprietary technology, Life cycle, potential return on investment, new market optional, timing for technology. The result is shown in Table 2:

Table 1. Description of technology selection criteria and their references

Criteria	Descriptions	References
Technological merit		
Advancement of technology	Level of advancement of the proposed technology compared with existing technology	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder,1993)
Innovation of technology	Innovation level of the proposed technology	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011)
Key of technology	Whether the proposed technology is critical for product or industry development	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011)
Proprietary technology	Whether the technology project will generate a proprietary technology position through the intellectual property rights	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011)
Generics of technology	Whether the proposed technology is a generic technology to industry	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
Technological connections	Whether the proposed technology is applicable for many products; the more technological applications, the higher technological connections	(Coldrick et al., 2005; Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011)
Technological extendibility	The extent to which the proposed technology has the potential for further technology development	(Huang, Chu & Chiang, 2008; Shen et al., 2010; Shen, Lin & Tzeng, 2011)
Productivity	Increase in labor, material, and capital productivity due to adoption of the new technology.	(Anand & Kodali, 2009; Bayazit, 2005; Jiang, et al., 1997; Grant & Gregory, 2011; Meade & Presley, 2002; Tonge et al., 2000)
Life Cycle	the stage status of the technology life cycle (research and development (R&D), ascent, maturity, decline)	(Farooq & O'Brien, 2009; Grant & Gregory, 2011; Jiang, et al., 1997; Meade & Presley, 2002; Yap & Souder,1993)
Production speed	The speed of production technology	(Bayazit, 2005; Eraslan & Dağdeviren, 2010)
Quality	Increase in product quality (lower defect rates) and process quality (improved control measures) due to adoption of the new technology.	(Jiang, et al., 1997; Ordoobadi, 2012; Shehabuddeen et al., 2006; Tan, et al., 2011)
Business effect		
Potential return on investment	The potential return on investment in the technology	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
Effect on existing market share	Whether the technology can enlarge the existing market share	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
New market potential	Whether the technology has the potential to create a new market	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
Potential size of market	The potential size of the market in which the products apply the technology	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
Timing for technology	Whether this is the right time to develop the technology	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al., 1998)
Cost	Initial cost of the technology acquisition and other related costs throughout the life of the technology.	(Grant & Gregory, 2011; Ordoobadi, 2012; Shehabuddeen et al., 2006; Yu et al., 1998)
Technology development potential		
Technical resources availability	Access to which the technology can obtain technical resources	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder,1993)
Equipment support	Extents to technology that can be supported by necessary facilities	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder,1993)
Opportunity for technical success	Opportunity of success for proposed technology and whether there is any similar successful technology	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder,1993)
Maintainability	repair or replace faulty or worn-out components without having to replace still-working parts	(Chan, et al., 2000; Grant & Gregory, 2011; Jiang, et al., 1997; Shehabuddeen et al., 2006)
Risk		
Commercial risk	Potential commercial risk of the applications	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder, 1993; Yu et al. 1998)

Technical risk	Potential technical risk of the technology development	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yap & Souder, 1993; Yu et al. 1998)
Technical difficulties	Whether the applications can be mass produced	(Shen et al., 2010; Shen, Lin & Tzeng, 2011; Yu et al. 1998)

Table 2. The sifting result of important technology selection criteria.

Criteria	Entropy	Result
Advancement of technology	0.979051	Cancel
Innovation of technology	0.994432	
Key of technology	0.972913	Cancel
Proprietary technology	0.929533	Cancel
Generics of technology	0.987359	
Technological connections	0.989747	
Technological extendibility	0.994432	
Productivity	0.992773	
Life cycle	0.964106	Cancel
Production speed	0.988039	
Quality	0.985954	
Potential return on investment	0.970692	Cancel
Effect on existing market share	0.992773	
New market potential	0.964408	Cancel
Potential size of market	0.987984	
Timing for technology	0.979595	Cancel
Cost	0.995331	
Technical resources availability	0.990754	
Equipment support	0.990754	
Opportunity for technical success	0.984609	
Maintainability	0.984609	
Commercial risk	0.981739	
Technical risk	0.983618	
Technical difficulties	0.984609	

Figure 2 shows the developed model composed of the goal, 4 criteria, 17 sub-criteria, and 4 alternatives.

Identify Inner Dependence and Outer Dependence Based on NRM by DEMATEL

Since we hypothesized that all factors within the model are interrelated, to prioritize criterion and alternatives all these relations should be considered. For this reason, the ANP method was applied for making decision about selecting appropriate alternatives. To compose ANP supermatrix, these relation should be determined which are shown in general as W_{22} and W_{33} in (7) relation. W_{22} indicates internal relations in criteria and W_{33} indicates internal relations in sub-criteria. According to viewpoint of experts, DEMATEL is one of main methods for determination of relations of factors within a model.

Data related to the calculations of this technique is obtained from experts through common questionnaires on DEMATEL technique. The questionnaires were filled out by the experts in the presence of the researcher so that the obtained data was precise and it was done thoroughly and in accordance with the purpose of the study. When the total relation matrix T was obtain with the help of steps 1 to 3, all calculations related to steps 1 to 3 were written by Algorithm soft were in MATELAB soft were. Through Equations (4)–(6), the total-relation matrix of four dimensions (technological merit, business effect, Technology development potential, and risk) are shown as Table 3.

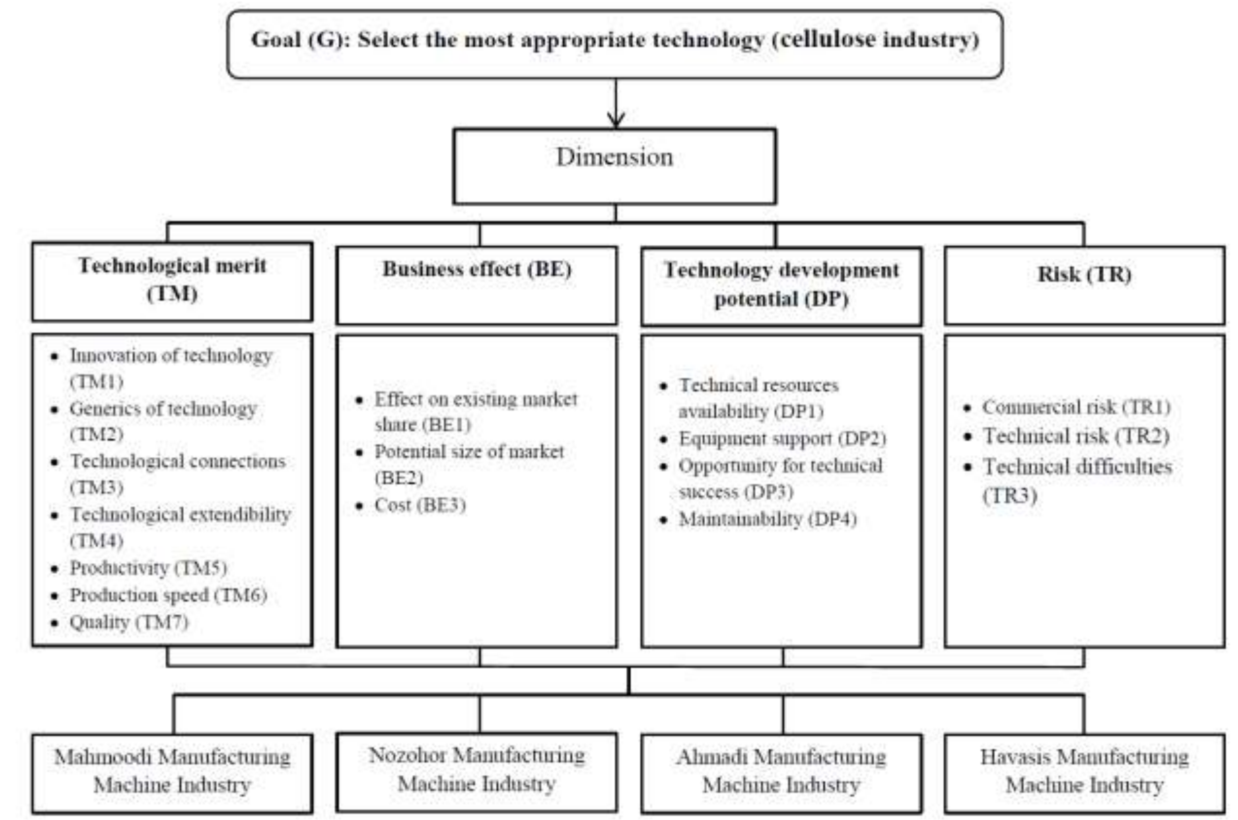

Figure 2. Final Model of Technology Selection in Cellulose Industry

As it was mentioned DEMATEL method determines the relationship among dimensions and criteria as well as drawing the impact- direction map to show causal relationship among “dispatchers” and “receivers”. For drawing the impact- direction map, the sum of rows and the sum of columns in total- relation matrix T are respectively as vector (V) and vector (c). The vector r represents the level of impact to others, whereas vector c indicates the level of relationship with others. The value of r+c known as "prominence" indicates the importance of factors. In the similar way, the value of r-c known as "relation" divvied factors in to dispatches and receivers (Shen, Lin and Tzeng, 2011; WU, 2008). Dispatchers are factors with positive values of r-c, having greater influence or one another, and higher priority. While receives are factors with negatives values of r-c receiving more influence from one another with lower priority.

On the other hand, the value r+c shows the degree of relation between each factor with others, therefore factors with more values of r+c have more relationship with one another, while those with little values of r+c have less relationship with others (Seyed-Hosseini, Safae and Asgharpour, 2006; Shen, Lin and Tzeng, 2011).

In this case vector r and vector c in the total relation matrix T of four main dimensions as it is shown in Table 3 are calculated to draw the impact direction map to indicate the major causal relationship among the dimensions. The value of prominence and relation in the matrix T of technological merit, business effect and risk are similarly derived by using Equations (4)-(6).

$$super\ matrix = \begin{bmatrix} 0 & 0 & 0 & 0 \\ W_{21} & W_{22} & 0 & 0 \\ 0 & W_{32} & W_{33} & 0 \\ 0 & 0 & W_{34} & 0 \end{bmatrix} \quad (7)$$

It should be noted that on the base of mentioned points, the only application of this Technique is not determination of relations and drawing NRMs. But the other application is applying matrix T to obtain W_{33} inputs and W_{22} inputs supermatrix ANP which will be elaborated in following section.

The impact-direction map of the four main dimensions is shown in Figure 3.

Table 3. The total-relation matrix t of four dimensions

	Technological merit	Business effect	development potential	Risk
Technological merit	0.172029174	0.552567951	0.458158296	0.547191186
Business effect	0.147893962	0.090376156	0.119020211	0.17575957
development potential	0.221435709	0.375503725	0.122913487	0.418069775
Risk	0.146694733	0.141904405	0.133292357	0.096187806

Table 4. The Values of Prominence and Relation.

Criteria	r	c	r+c	r-c
Technological merit	**1.729947**	**0.688054**	**2.418**	**1.041893**
Innovation of technology	1.798316	0.353622	2.151938	1.444694
Generics of technology	0.272889	0.396859	0.669748	-0.12397
Technological connections	0.234316	0.332852	0.567168	-0.09854
Technological extendibility	1.023726	0.597209	1.620935	0.426517
Productivity	0.903295	1.61466	2.517954	-0.71136
Production speed	0.768385	1.415592	2.183978	-0.64721
Quality	1.14051	1.430642	2.571153	-0.29013
Business effect	**0.53305**	**1.160352**	**1.693402**	**-0.6273**
Effect on existing market share	1.666388	0.686898	2.353286	0.979489
Potential size of market	0.686898	1.666388	2.353286	-0.97949
Cost	0.174131	0.174131	0.348263	0
Technology development potential	**1.137923**	**0.833384**	**1.971307**	**0.304538**
Technical resources availability	2.148572	0.919449	3.068021	1.229124
Equipment support	2.002097	1.168026	3.170123	0.834072
Opportunity for technical success	0.509638	1.660644	2.170282	-1.15101
Maintainability	0.908618	1.820808	2.729426	-0.91219
Risk	**0.518079**	**1.237208**	**1.755288**	**-0.71913**
Commercial risk	0.072178	1.805376	1.877554	-1.7332
Technical risk	1.5984	0.759304	2.357703	0.839096
Technical difficulties	1.529407	0.635304	2.164711	0.894103

Perform Pairwise Comparison to Determine Criteria and Alternatives Priorities.

As it was mentioned earlier ANP is general and it is the extension of AHP. Therefore like AHP, pairwise comparisons within both levels and upper levels can be made with final compose W_{21}, W_{32} and W_{34}, supermatrix. These comparisons obtained from experts judgment by questionnaires. These questions were filled out like the way DEMATEL questionnaires were done that is by the presence of the researcher to ensure that participants realize the questions, the aim of the study, the questionnaire and finally the main aim of the study. The questionnaires were posed to seven experts all were CEOs.

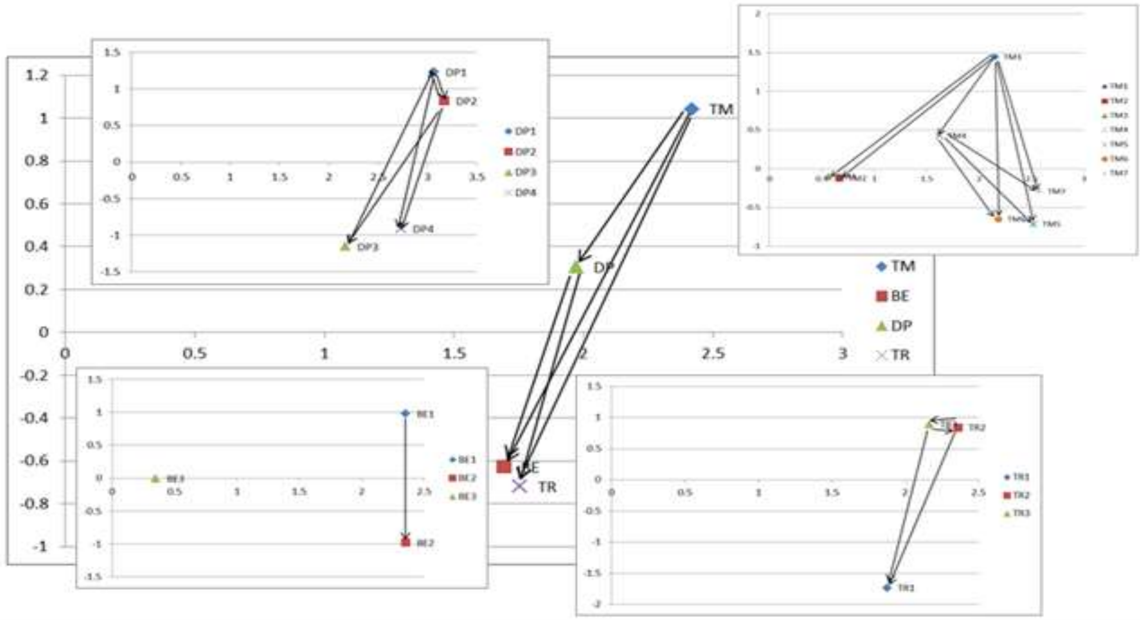

Figure 3. The impact-Direction Map

The relative importance of factors in questionnaires was measured based on quadratic 9 quantitative scale. Then in order to integrate experts' judgments Geometric Mean was calculated in the obtained matrix. After entering the results of pairwise comparisons in Super Decision software the consistency ratio (CR) was evaluated and the value of the CR should be 0.1 or less to confirm the comparisons (Ordoobadi, 2012). In the first phase the relative importance of each criterion with respect to the goal that is selecting the best tissue production technology, is determined. The pairwise comparison convergence matrix of criteria with respect to the goal is in table 5. In the second phase, pairwise comparison of each sub-criterion is done according to its criteria. Ultimately priority of each criteria and sub-criterion will be determined according to pairwise comparisons (Lee, Lee and Park, 2009).

Results of convergence in each of mentioned comparisons were interned to SuperDecision software and the (CR) was controlled in the software as well.

CR = 0.01356

Table 5. The pairwise comparison convergence matrix of with respect to the goal.

	Technological merit	Business effect	development potential	Risk
Technological merit	1	3.788434	2.318388	5.30083
Business effect	0.263999	1	0.634987	2.900723
development potential	0.431211	1.57461	1	3.803711
Risk	0.188757	0.344296	0.262939	1

Integration of DEMATEL and ANP Method to Provide Super Decision Input

Saaty (1996) states that the function of ANP method is to avoid the hierarchical constrains which are in the AHP method. In this study, ANP and DEMATEL were used to calculate the relative weights of the factors. If the traditional ANP applied to calculate the relative weight of factors, then the levels of interdependence of factors are treated as reciprocal values.

However, According to DEMATEL method, the levels of interdependences of factors do not have reciprocal value and it is closer to the real system (Vujanović et al., 2012, Yang and Tzeng, 2011). In order to avoid shortcoming in ANP, total relation matrix in DEMATEL is applied to calculate relative weight of factors.

DEMATEL method is not used to calculate the level of impact in different factors but the normalized total- influence matrix will be incorporated into un-weighted supermatrix W in the ANP to calculate the level of inter dependence of different factor (Lee *et al.,* 2011; Vujanović et al., 2012).

After providing W_{21}, W_{32} and W_{34} related to unweighted supermatrix through pairwise comparisons to complete unweighted supermatrix, W_{33} and W_{22} should be added.

To obtain normalized total relation matrix, considering threshold value related to the matrix, we omit minimal criteria effect on each other, which are less than threshold value. Then we use final matrix as W_{22} and W_{33} in unweighted supermatrix. For example the total relation matrix related to criteria shown in Table 3.

W_{22} is only composed of normalized total relation matrix but W_{33} is composed of normalized total relation matrix related to 4 sub-criteria clusters. In this phase Super Decision first starts with determination of interrelation in each cluster and then ends entering data into the software by selecting "direct" icon.

Construct ANP Supermatrix in Super Decision and Select the Technology Alternative with the Highest Priority

After integrating ANP and DEMATEL methods, and getting W_{21}, W_{32}, W_{34}, W_{22}, and W_{33}, which are elements comprising supermatrix, it is time to place each part in its place base on plan of relation (7) to compose supermatrix. In next step, weighted supermatrix is composed. In order to have weighted supermatrix, unweighted supermatrix should just be normalized.

This step and all other steps are done by "SuperDecision" software to prioritize alternatives. Weighted supermatrix and unweighted supermatrix are shown in (6)-(7) tables respectively. The next step is to obtain limit supermatrix. This step is the final one for obtaining total priority of alternatives. In forth step, we calculated a limited supermatrix by several multiplying of weighted supermatrix W to stabilize the vector value in a limited supermatrix. In other words,

$$\lim_{k \to \infty} W^{2k+1} \qquad (8)$$

while the number k tends to infinity. Relative weights of each factor in relation to the defined objectives are represented by vectors of limited supermatrix (Vujanović *et al.,* 2012).

Final results of priority of alternative technologies are in Table 8. It should be mentioned that all calculations was done by Super Decision software.

Table 8. Final results of priority of alternative technologies from super decision.

Name	Ideals	Normal	Raw
Mahmoodi Manufacturing Machine Industry	0.155940	0.067126	0.033563
Nozohor Manufacturing Machine Industry	0.290649	0.125113	0.062552
Ahmadi Manufacturing Machine Industry	1.000000	0.430461	0.215231
Havasis Manufacturing Machine Industry	0.876501	0.377300	0.188650

Table 6. Unweighted supermatrix

Clusters & Nodes		G	D				TM							BE			DP				TR			AL			
		G	TM	BE	DP	TR	TM1	TM2	TM3	TM4	TM5	TM6	TM7	BE1	BE2	BE3	DP1	DP2	DP3	DP4	TR1	TR2	TR3	AL1	AL2	AL3	AL4
G	G	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D	TM	0.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE	0.219	0.275	0.000	0.483	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP	0.266	0.462	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TR	0.419	0.262	0.000	0.517	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TM	TM1	0.000	0.142	0.000	0.000	0.000	0.000	0.000	0.000	0.640	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM2	0.000	0.040	0.000	0.000	0.000	0.251	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM3	0.000	0.044	0.000	0.000	0.000	0.251	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM4	0.000	0.109	0.000	0.000	0.000	0.251	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM5	0.000	0.205	0.000	0.000	0.000	0.076	0.000	0.000	0.120	0.000	0.491	0.557	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM6	0.000	0.232	0.000	0.000	0.000	0.084	0.000	0.000	0.115	0.491	0.000	0.442	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM7	0.000	0.227	0.000	0.000	0.000	0.086	0.000	0.000	0.124	0.510	0.509	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BE	BE1	0.000	0.000	0.137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE2	0.000	0.000	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE3	0.000	0.000	0.745	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DP	DP1	0.000	0.000	0.000	0.160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.505	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP2	0.000	0.000	0.000	0.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.494	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP3	0.000	0.000	0.000	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.257	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP4	0.000	0.000	0.000	0.511	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.248	0.252	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TR	TR1	0.000	0.000	0.000	0.000	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.350	0.317	0.000	0.000	0.000	0.000
	TR2	0.000	0.000	0.000	0.000	0.334	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.683	0.000	0.000	0.000	0.000
	TR3	0.000	0.000	0.000	0.000	0.451	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.651	0.000	0.000	0.000	0.000	0.000
AL	AL1	0.000	0.000	0.000	0.000	0.000	0.048	0.228	0.201	0.067	0.058	0.127	0.052	0.056	0.055	0.510	0.328	0.327	0.085	0.376	0.135	0.267	0.294	0.000	0.000	0.000	0.000
	AL2	0.000	0.000	0.000	0.000	0.000	0.135	0.619	0.234	0.127	0.107	0.127	0.113	0.137	0.134	0.425	0.368	0.369	0.120	0.417	0.604	0.460	0.463	0.000	0.000	0.000	0.000
	AL3	0.000	0.000	0.000	0.000	0.000	0.461	0.100	0.328	0.504	0.458	0.343	0.461	0.439	0.438	0.041	0.240	0.120	0.450	0.160	0.187	0.191	0.182	0.000	0.000	0.000	0.000
	AL4	0.000	0.000	0.000	0.000	0.000	0.356	0.052	0.236	0.302	0.376	0.403	0.373	0.368	0.373	0.023	0.062	0.059	0.265	0.048	0.073	0.081	0.061	0.000	0.000	0.000	0.000

Table 7. Weighted supermatrix

Clusters & Nodes		G	D				TM							BE			DP				TR			AL			
		G	TM	BE	DP	TR	TM1	TM2	TM3	TM4	TM5	TM6	TM7	BE1	BE2	BE3	DP1	DP2	DP3	DP4	TR1	TR2	TR3	AL1	AL2	AL3	AL4
G	G	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
D	TM	0.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE	0.219	0.138	0.000	0.241	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP	0.266	0.231	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TR	0.149	0.131	0.000	0.258	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TM	TM1	0.000	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM2	0.000	0.020	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM3	0.000	0.022	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM4	0.000	0.054	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM5	0.000	0.102	0.000	0.000	0.000	0.038	0.000	0.000	0.060	0.000	0.246	0.279	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM6	0.000	0.116	0.000	0.000	0.000	0.042	0.000	0.000	0.058	0.245	0.000	0.221	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TM7	0.000	0.113	0.000	0.000	0.000	0.043	0.000	0.000	0.062	0.254	0.254	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BE	BE1	0.000	0.000	0.137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE2	0.000	0.000	0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	BE3	0.000	0.000	0.745	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DP	DP1	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.253	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP2	0.000	0.000	0.000	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP3	0.000	0.000	0.000	0.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.128	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DP4	0.000	0.000	0.000	0.256	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.124	0.126	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TR	TR1	0.000	0.000	0.000	0.000	0.215	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.174	0.158	0.000	0.000	0.000	0.000
	TR2	0.000	0.000	0.000	0.000	0.334	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.342	0.000	0.000	0.000	0.000
	TR3	0.000	0.000	0.000	0.000	0.451	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.325	0.000	0.000	0.000	0.000	0.000
AL	AL1	0.000	0.000	0.000	0.000	0.000	0.024	0.228	0.201	0.033	0.029	0.063	0.026	0.028	0.027	0.510	0.164	0.171	0.085	0.375	0.135	0.134	0.147	0.000	0.000	0.000	0.000
	AL2	0.000	0.000	0.000	0.000	0.000	0.067	0.619	0.234	0.063	0.053	0.063	0.056	0.069	0.067	0.425	0.185	0.200	0.200	0.417	0.604	0.230	0.232	0.000	0.000	0.000	0.000
	AL3	0.000	0.000	0.000	0.000	0.000	0.230	0.100	0.328	0.252	0.229	0.172	0.231	0.219	0.219	0.041	0.120	0.100	0.449	0.159	0.187	0.095	0.091	0.000	0.000	0.000	0.000
	AL4	0.000	0.000	0.000	0.000	0.000	0.178	0.052	0.236	0.151	0.188	0.201	0.184	0.184	0.186	0.023	0.031	0.029	0.265	0.048	0.073	0.041	0.030	0.000	0.000	0.000	0.000

Concluding Remarks

An enterprise or a country's technological advantage or disadvantage is highly bond to technology selection- a multi- criteria decision- making problem. Technology provides major source of competitive situations, which are beneficial. To realize the competitive benefits from technologies, each technology alternative must be critically evaluated. These types of decision making problems have encountered decision makers with various economic or industrial problems such as cost, risk, potential benefits, and limited resources. On the other hand, since the number of technologies is increasing, technology selection is not easy. This study enjoys a hybrid process to challenge technology selection. Technology selection process in this study composed of six steps.

It seems that the technique such as ANP, which assumes the criteria independent, is not an effective way, because various economic and industrial prospects is highly influential in decision making of technology selection. Taking economic and industrial criteria in to account, the combination of DEMATEL and ANP is employed for technology selection model. DEMATEL indicates interdependent relationship among criteria as well as constructing the network relation map for ANP by group judgment.

Furthermore, after selecting appropriate model, the model was developed according to the required criteria. In order to have introduced criteria with cellulose industry the model was sifted through Shannon Entropy method and expert`s judgment and unrelated criteria was omitted.

Moreover, the network relation maps help decision makers to determine which dimension and criterion is the dispatcher which influences other dimensions and criteria in the system. Through this information, decision makers are provided with strategies for improvement of the performances of each technology fields On the other hand, visiting in 20th international detergent, hygienic, cellulose and related machinery exhibition that was hold on… in Tehran, alternative technologies in this industry accompanied with mechanical and quality features were gathered and 4 of them were chosen as competitive candidates in selection after consulting with some experts process.

In this process, the economical and industrial prospects as well as critical technology were taken in to account to have a very effective technology selection that is by combining the technological selection model constructed by Shannon Entropy method, DEMATEL, and ANP. Presented model and process in this study provides a guideline for managers in cellulose industry to make wise decisions, to select different technologies in other parts of cellulose industry. Moreover, the value of technology field would be enhanced by the impact direction map drawn by the DEMATEL method. To verify the technology selection process proposed in this study we take cellulose industry to select appropriate technology field for the industry in Iran. The result indicates that the Technological merit is of most concern. This result verifies that Ahmadi Manufacturing Machine Industry is the most proper technology for tissue production and the production speed and the Technological extendibility are the most critical sub-criteria of technology selection model for tissue production technology. Future research should apply this hybrid process to verify its applicability by demonstrations on other cellulose industry technologies.

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