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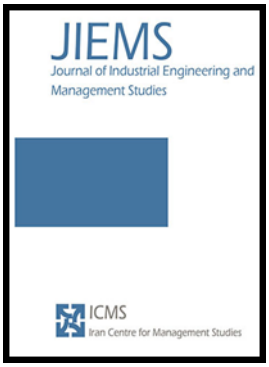

Identifying and ranking effective lean production factors on economic performance of production companies in Mazandaran province of Iran based on FDANP approach

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Abstract

This paper identified and ranked the lean product factors effecting economic function of production companies in Mazandaran province. 24 sub-factors and five main factors were categorized including supplier management, purchase and provision system, human resource organization, organizing, leadership, and IT. The findings of the paper show that the factor of supplier management is the most influential factor in economic function of production companies and IT has the least effect on the economic function of production companies.

Keywords: Lean production; Economic function; FDANP approach

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1. Introduction

Lean is concern of a learning based manufacturing organizations that focuses on continuous improvements. The roots of it is founded in Toyota Production System. Thus, it is optimizing process by reducing unnecessary steps and elimination of waste (which is not adding value). According to lean manufacturing principals, there are 7 MUDAs or seven types of waste that can be found in a manufacturing process such as defects of requiring rework, Over-Processing, and movement of materials or people, waiting time, excess inventory and overproduction. These days, life cycle perspective is considering to cover different aspects and all stages from primary stage including as product development, procurement and manufacturing over to distribution (Womack et al., 1996). It is a methodology to attain the highest quality, lowest cost, and shortest lead time. It is an impact of a complex, pro-quality management in all areas of enterprise activities (Wyrwicka. & Mrugalska, 2015).

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It can be also considered as an extended just-in-time including all sections of supply chain, intra and inter- organization (Grzybowska et al., 2016; Gumzej R, Gajšek, 2012). Thus, it is a multi-dimensional methodology that can enhance system to deliver products to the customer with minimum waste (Shah & Ward, 2003; Mrugalska & Ahram, 2016).

2. Literature review

2.1. Lean Production

Lean is an integrated system of principles, practices, tools, and techniques that mainly focus on waste reduction, through synchronizing work flows, and managing production flows (Zugelder, 2012) that benefits in enhancing Productivity. Lean manufacturing has been used to effectively improve organization performance in the long term. According to Ohno (1997), lean manufacturing consists of a work management philosophy that meets customer demands in the shortest possible time at the highest quality and the lowest cost. For Shah and Ward (2007), lean production is conceptually compounded by multiple attributes covering philosophical characteristics that are often difficult to measure directly. Lean manufacturing has been adopted by companies around the world for several decades, and also got much attention from the academia (Jasti and Kodali 2015). A large number of publications have studied the relationship between lean manufacturing adoption and Economic performance. Some examples of such studies are Fullerton, Kennedy, and Widener (2014), Gao and Low (2014), Green et al. (2014), Ghosh (2013), Nawanir, Teong, and Othman (2013), Chen and Tan (2013), among others. Each one of those publications focused in a particular geographical location and/or industry. For instance, Fullerton, Kennedy, and Widener (2014) surveyed only US manufacturing companies, while Ghosh (2013) target Indian manufacturing firms, and Chen and Tan (2013) collected data from Chinese companies. This research aims to identify and rank the lean manufacturing factors affecting the economic performance in Mazandaran Province

2.2. Lean implementation

Organizational characteristics are factor of successful implementation for any management practice.

Generally, the successful implementation of any management practice often relies on organizational characteristics. However, it should be emphasized that not all organizations can or even should implement the same set of practices (Mrugalska & Wyrwicka, 2017). The most common practices of lean production are: bottleneck removal (production smoothing), cellular manufacturing, competitive benchmarking, continuous improvement programs, cross-functional work force, cycle time reductions, focused factory production, just-in-time/continuous flow production, lot size reductions, maintenance optimization, new process equipment/technologies, planning and scheduling strategies, preventive maintenance, process capability measurements, pull system/Kanban, quality management programs, quick changeover techniques, reengineered production process, safety improvement programs, self-directed work teams, total quality management (Shah & Ward, 2003). Although, it should be highlighted that these methodologies create a system to help elimination of a specific type of waste and they should be applied together. The following approaches are often known as "lean toolbox" (Wyrwicka. & Mrugalska, 2015). As far as the implementation process of lean production is concerned there are discussed diverse frameworks. According to Ålström (Ålström, 1998) Improvement activities and process become visible in the sequence in manufacturing obviously, however, introducing process continuous improvement at the end is

necessary to show the advantage of it against former established other principles. Storhagen (Storhagen, 1993) suggests that job rotation and teamwork can support continuous improvement and change that allowed lean implementation taking the advantage in the beginning. Besides, it is recommended to change that employees' attitudes towards quality by material flow which contains only value adding operations (Roos, 1990). Following Womack and Jones's "lean leap process" (Womack & Jones, 1996) identifying a change factor for creating a new lean organization is mandatory. Such person should be the first one who acquires lean knowledge to be able to share it with the rest of organization before mapping value streams. Accordingly, business systems should be fixed. Lean thinking can be recognized as completed when it is applied to suppliers and customers, a global strategy is developed, and continuous improvement program is transitioned from a top-down to a bottom up. Additionally,

A step-by-step implementation of lean principles which is proposed by Hobbs (Hobbs, 2004) is as following table (Table 1):

Table 1. Lean steps and principles

Step	Lean Principle
Establish strategic vision	-
Identify and establish teams	-
Identify products	Value
Identify processes	Value stream
Review factory layout	Flow
Select appropriate pull strategy	Pull
Continuously improve	Perfection

2.3. Lean production methodology

Lean effective production indices on economic function of production- oriented companies in Mazandaran province after studying the review of literature It should be highlighted that an internal research (Seyed Hosseini & Bayat Tork, 2004) has been considered as well to make sure the applicable lean factors in Iran has being analyzing. The results are shown below (Table2).

Table 2. Indices of effective lean production on economic function of production -oriented companies in Mazandaran province lean (Seyed Hosseini & Bayat Tork, 2004)

Acronym	key factors	stage name
C11	Number of suppliers	Suppliers' management (C1)
C12	Suppliers evaluation	
C13	Materials and items price fluctuations	
C14	Sending items schedule	
C15	Stability of suppliers cooperation	
C21	Presence of technical features of the purchased items	Purchase and provision system (C2)
C22	Method of controlling items quality	
C23	Method of reaction to unacceptable faults	
C24	Implementation of JIT system	
C25	Items transfer system	
C31	Suggestions committee activities	Organization of human resources (C3)
C32	The suitability of position and responsibilities	
C33	Staff training opportunity	
C34	Utilizing motivational system	
C35	Contribution of employees facing changes	
C41	Strategic planning	Organization and leadership (C4)
C42	Carrying out duties according to regulations	
C43	Management's attitude toward human resources	
C44	Decision- making and concentration ability	
C45	°S implementation	
C51	Information availability	IT (C5)
C52	Information updating	
C53	System intelligence information	
C54	Speed of information circulation	

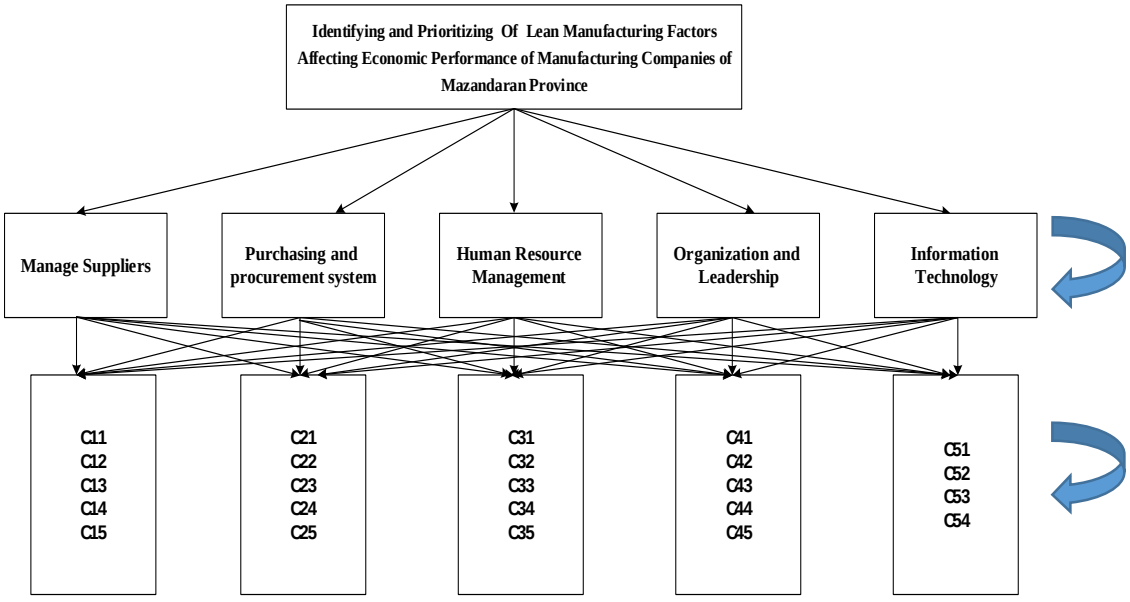

Figure 1. The research network model

3. Research methodology

The present study is an applied-descriptive on. The population used in the study includes experts at lean production- oriented companies sector in Mazandaran province.

To extract lean factors in Mazandaran province, take sample based on theory (2008) the researcher applied 10 experts at lean production sector who are knowledgeable enough and used Judgment sampling. These individuals were MA holders or earned PhD and had 10 years of experience. In the present study, the author used combined method of fuzzy DEMATEL based on ANP (FDANP) to analyze data.

To collect data, the researcher studied research articles and categorized the factors in five main factors containing 24 sub-factors. In addition to that, to gather data, the researcher used two questionnaires (screening and even scaling)

3.1. Data analysis

In order to analyze collected data from the questionnaires and determining the relations and effective or effected factors and sub-factors, first the author used fuzzy DEMATEL.

Decision method to determine effective and effected factors and sub-factors then with the help of combined method of Fuzzy DEMATEL based on ANP ranked factors and sub-factors.

3.2. Fuzzy DEMATEL based on ANP (FDANP) method

The steps of this method are as follows: (Chiu, Tzeng, & Li, 2013)

Creating the matrix of direct relationships by determining the impact of criterion i on criterion j with the help of Table 3.

Table 3. Verbal criteria for pair-wise comparisons

Verbal Expressions for Pair-Wise Comparisons	Fuzzy Numbers
Very High Impact	(0.75, 0.75, 1)
High Impact	(0.5, 0.75, 1)
Low Impact	(0.25, 0.5, 0.75)
Very Low Impact	(0, 0.25, 0.5)
No Impact	(0, 0, 0.25)

Step 1: Calculation of direct relationships matrix ($\tilde{z}$).

In this step, respondents were asked to show the impact of criterion i on the j criterion using Table 3. In order to examine the criteria, the opinions of 10 experts were used. To consider the views of all the experts through equation 1 mathematical average is applied.

$$\tilde{z} = \frac{\tilde{x}^1 \oplus \tilde{x}^2 \oplus \tilde{x}^3 \oplus \ldots \oplus x^p}{p} \quad (1)$$

In this equation p denotes the number of experts and $\tilde{x}^1, \tilde{x}^2, \tilde{x}^p$ are accordingly, the comparison matrix is the expert 1, expert 2 and expert p. The experts' average views is shown in Table 3.

Step 2: Normalization of Matrix $\tilde{z}$ ($\widetilde{H}_{ij}$) In order to normalize matrix$\tilde{z}$, the following equations are used.

$$\widetilde{H}_{ij} = r \times \tilde{z}_{ij} = (r \times l'_{ij}, r \times m'_{ij}, r \times u'_{ij}) = (l''_{ij}, m''_{ij}, u''_{ij}) \quad (2)$$

r is obtained through the following formula:

$$r = min\left\{\frac{1}{max_{1\le i\le n}\sum_{j=1}^{n} a_{ij}}, \frac{1}{max_{1\le i\le n}\sum_{i=1}^{n} a_{ij}}\right\}$$

Step 3: at this step total relationship matrix is calculated using the equation 3:

$$\tilde{T}_C = \lim_{k\to+\infty}(\tilde{H}^1 \oplus \tilde{H}^2 \oplus \ldots \oplus \tilde{H}^k) \quad (3)$$

Each of which is a fuzzy number in the form $\tilde{t}_{ij} = (l^t_{ij}, m^t_{ij}, u^t_{ij})$ and is calculated as follows Steps:

$$[l^t_{ij}] = H_l \times (I - H_l)^{-1} \quad (4)$$

$$[m^t_{ij}] = H_m \times (I - H_m)^{-1} \quad (5)$$

$$[u^t_{ij}] = H_u \times (I - H_u)^{-1} \quad (6)$$

Step 4: Calculation of the matrix of full relationship of the main indicators ($\widetilde{\boldsymbol{T}}_{\mathbf{D}}$).

Step 5: Calculation of intensity and direction of impact

According to equations 7 and 8 the $\tilde{d}_j$ and $\tilde{r}_i$ values are calculated. The $\tilde{r}_i$ index denotes the sum of the rows i and the index $\tilde{d}_j$ represents the sum of column j from the matrix $\tilde{T}_C$ with respect to the corresponding dimension. Similarly, we calculate the $\tilde{R}_i$ and $\widetilde{D}_j$ indices. The index $\tilde{R}_i$ represents the sum of the rows i and the index $\widetilde{D}_j$ represents the sum of the j column of the $\tilde{T}_{\mathbf{D}}$ matrix. For each i = j we will have:

$$\tilde{R} = \left(\tilde{R}_i\right)_{n\times 1} = \left[\sum_{j=1}^{n} \tilde{T}_{ij}\right]_{n\times 1} \quad (7)$$

$$\widetilde{D} = \left(\widetilde{D}_j\right)_{1\times n} = \left[\sum_{i=1}^{n} \tilde{T}_{ij}\right]_{1\times n} \quad (8)$$

Where $\tilde{R}$ and $\widetilde{D}$ are n×1 and 1×n, respectively.

The next step will determine the importance of the indices ($\tilde{R}_i + \tilde{D}_j$) and the relationship between the measures ($\tilde{R}_i - \tilde{D}_j$). If ($\tilde{R}_i - \tilde{D}_j$) > 0, then the relevant measure is influential and if ($\tilde{R}_i - \tilde{D}_j$) < 0, then the relevant measure is permeable.

$\tilde{r}_i + \tilde{d}_j$ = Intensity of influence and permeability (in other words, the more $\tilde{r}_i + \tilde{d}_j$, the higher the measure, the more interacting with the other system measures).

$\tilde{r}_i - \tilde{d}_j$ = the direction of influence or permeability (so that if ($\tilde{r}_i - \tilde{d}_j$) > 0 the relevant measure is influential and if ($\tilde{r}_i - \tilde{d}_j$) < 0, then the relevant measure is permeable.

Table 4. The values of $\tilde{R}$, $\tilde{D}$, $\tilde{R} + \tilde{D}$, and $\tilde{R} - \tilde{D}$

Criteria/Sub-Criteria	$\tilde{R}$	$\tilde{D}$	$\tilde{R} + \tilde{D}$	$\tilde{R} - \tilde{D}$	R+D	R-D	Effectiveness condition
Manage Suppliers	(0.232,0.7202,9.0986)	(0.2307,0.7177,9.1181)	(0.4627,1.4379,18.2167)	(0.0013,0.0025,-0.0195)	5.3888	-0.0033	Permeable
Number of suppliers	(0.2168,0.6912,8.9177)	(0.2135,0.6961,9.1334)	(0.4303,1.3873,18.0511)	(0.0033,-0.0049,-0.2157)	5.314	-0.0556	Permeable
Suppliers evaluation	(0.2089,0.6929,9.0888)	(0.212,0.683,8.9937)	(0.4209,1.3759,18.0825)	(-0.0031,0.0099,0.0951)	5.3138	0.028	Influential
Materials and items price fluctuations	(0.209,0.6802,9.0714)	(0.2061,0.6825,9.0679)	(0.4151,1.3627,18.1393)	(0.0029,-0.0023,0.0035)	5.32	0.0005	Influential
Sending items schedule	(0.2108,0.6986,9.1461)	(0.2204,0.7083,9.1374)	(0.4312,1.4069,18.2835)	(-0.0096,-0.0097,0.0087)	5.3821	-0.0051	Permeable
Stability of suppliers cooperation	(0.2116,0.6883,9.1799)	(0.2051,0.6813,9.0715)	(0.4167,1.3696,18.2514)	(0.0065,0.007,0.1084)	5.3518	0.0322	Influential
Purchasing and procurement system	(0.2358,0.7279,9.1925)	(0.2354,0.7272,9.1781)	(0.4712,1.4551,18.3706)	(0.0004,0.0007,0.0144)	5.438	0.0041	Influential
Presence of technical features of the purchased items	(0.2152,0.6949,9.1357)	(0.2123,0.6904,9.2025)	(0.4275,1.3853,18.3382)	(0.0029,0.0045,-0.0668)	-0.0137	5.3841	Influential
Method of controlling items' quality	(0.2196,0.704,9.228)	(0.2197,0.7087,9.2409)	(0.4393,1.4127,18.4689)	(-0.0001,-0.0047,-0.0129)	-0.0056	5.4334	Influential
Method of reaction to unacceptable faults	(0.2307,0.7331,9.297)	(0.2257,0.7199,9.2761)	(0.4564,1.453,18.5731)	(0.005,0.0132,0.0209)	0.0131	5.4839	Influential
Implementation of JIT system	(0.2202,0.7036,9.3191)	(0.225,0.7202,9.2616)	(0.4452,1.4238,18.5807)	(-0.0048,-0.0166,0.0575)	0.0049	5.4684	Influential
Items transfer system	(0.2131,0.7011,9.1932)	(0.2161,0.6975,9.1919)	(0.4292,1.3986,18.3851)	(-0.003,0.0036,0.0013)	0.0014	5.4029	Influential
Human Resource Management	(0.2361,0.7287,9.1821)	(0.2382,0.7337,9.1536)	(0.4743,1.4624,18.3357)	(-0.0021,-0.005,0.0285)	5.4337	0.0041	Influential
Suggestions committee activities	(0.226,0.7212,9.0965)	(0.2206,0.7044,9.1402)	(0.4466,1.4256,18.2367)	(0.0054,0.0168,-0.0437)	5.3836	-0.0012	Permeable
The suitability of position and responsibilities	(0.2188,0.7057,9.2829)	(0.2268,0.728,9.3089)	(0.4456,1.4337,18.5918)	(-0.008,-0.0223,-0.026)	5.4762	-0.0197	Permeable
Staff training opportunity	(0.2278,0.718,9.1986)	(0.2279,0.7222,9.2294)	(0.4557,1.4402,18.428)	(-0.0001,-0.0042,-0.0308)	5.441	-0.0098	Permeable
Utilizing motivational system	(0.2236,0.718,9.1827)	(0.2279,0.7163,9.1289)	(0.4515,1.4343,18.3116)	(-0.0043,0.0017,0.0538)	5.4079	0.0132	Influential
Contribution of employees facing changes	(0.2264,0.7178,9.2448)	(0.2194,0.7098,9.1981)	(0.4458,1.4276,18.4429)	(0.007,0.008,0.0467)	5.436	0.0174	Influential
organization and leadership	(0.2292,0.7095,9.0005)	(0.2395,0.7365,9.2)	(0.4687,1.446,18.2005)	(-0.0103,-0.027,-0.1995)	5.3903	-0.066	Permeable
Strategic planning	(0.2252,0.7109,9.0747)	(0.2169,0.7023,9.104)	(0.4421,1.4132,18.1787)	(0.2169,0.7023,9.104)	5.3618	-0.0009	Permeable

Criteria/Sub-Criteria	$\tilde{R}$	$\tilde{D}$	$\tilde{R}+\tilde{D}$	$\tilde{R}-\tilde{D}$	R+D	R-D	Effectiveness condition
Carrying out duties according to regulations	(0.2087,0.6805,8.9736)	(0.2184,0.6979,8.9571)	(0.4271,1.3784,17.9307)	(0.2184,0.6979,8.9571)	5.2787	-0.007	Permeable
Management's attitude toward human resources	(0.2269,0.712,9.1261)	(0.2192,0.6963,8.9741)	(0.4461,1.4083,18.1002)	(0.2192,0.6963,8.9741)	5.3407	0.0478	Influential
Decision- making and concentration ability	(0.2187,0.6935,8.9425)	(0.2333,0.7238,9.1853)	(0.452,1.4173,18.1278)	(0.2333,0.7238,9.1853)	5.3536	-0.0795	Permeable
5S implementation	(0.2286,0.7206,9.2122)	(0.2203,0.6972,9.1086)	(0.4489,1.4178,18.3208)	(0.2203,0.6972,9.1086)	5.4013	0.0397	Influential
Information Technology	(0.2298,0.7161,9.0775)	(0.2191,0.6873,8.9014)	(0.4489,1.4034,17.9789)	(0.0107,0.0288,0.1761)	5.3087	0.0611	Influential
Information availability	(0.164,0.5396,7.1393)	(0.177,0.5577,7.1588)	(0.341,1.0973,14.2981)	(-0.013,-0.0181,-0.0195)	4.2084	-0.0172	Permeable
Information updating	(0.1532,0.5149,7.0757)	(0.1605,0.529,7.0993)	(0.3137,1.0439,14.175)	(-0.0073,-0.0141,-0.0236)	4.1441	-0.0148	Permeable
System intelligence information	(0.1653,0.5306,7.0947)	(0.1372,0.4788,6.8788)	(0.3025,1.0094,13.9735)	(0.0281,0.0518,0.2159)	4.0737	0.0869	Influential
Speed of information circulation	(0.1525,0.5149,6.9984)	(0.1603,0.5345,7.1712)	(0.3128,1.0494,14.1696)	(-0.0078,-0.0196,-0.1728)	4.1453	-0.055	Permeable

Step 6: Normalizing the matrix of the complete relationship of the main factors (T_D^{α})

Given equation 9, we perform the normalization of the matrix. In this way, the sum of each row of the matrix is calculated with respect to the corresponding dimension, then the element of each row is divided into the sum of the elements of the same row and, in the end, the place of the row and column is changed.

$$T_D = \begin{bmatrix} t_{11}^{D_{11}} & \cdots & t_{1j}^{D_{1j}} & \cdots & t_{1m}^{D_{1m}} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}} & \cdots & t_{ij}^{D_{ij}} & \cdots & t_{im}^{D_{im}} \\ \vdots & \vdots & & \vdots & \vdots \\ t_{m1}^{D_{m1}} & \cdots & t_{mj}^{D_{mj}} & \cdots & t_{mm}^{D_{mm}} \end{bmatrix} \begin{matrix} \longrightarrow d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}} \\ \\ \longrightarrow d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \\ \\ \longrightarrow d_m = \sum_{j=1}^{m} t_{mj}^{D_{mj}} \end{matrix} \quad , d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} , i = 1,\ldots,m \tag{9}$$

$$T_D^{\alpha} = \begin{bmatrix} t_{11}^{D_{11}} / d_1 & \cdots & t_{1j}^{D_{1j}} / d_1 & \cdots & t_{1m}^{D_{1m}} / d_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_{i1}^{D_{i1}} / d_i & \cdots & t_{ij}^{D_{ij}} / d_i & \cdots & t_{im}^{D_{im}} / d_i \\ \vdots & \vdots & & \vdots & \vdots \\ t_{m1}^{D_{m1}} / d_m & \cdots & t_{mj}^{D_{mj}} / d_m & \cdots & t_{mm}^{D_{mm}} / d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & \cdots & t_D^{\alpha 1j} & \cdots & t_D^{\alpha 1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{\alpha i1} & \cdots & t_D^{\alpha ij} & \cdots & t_D^{\alpha in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ t_D^{\alpha m1} & \cdots & t_D^{\alpha mj} & \cdots & t_D^{\alpha mn} \end{bmatrix}$$

Step 7: Normalization of the matrix of complete relationship between sub-factors and the formation of unweighted super-matrix using Equations 10 to 12:

We normalize the matrix $\tilde{T}_C$ using the following relations; in this step, the sum of each row of $\tilde{T}_C$ is calculated according to the corresponding dimension, and then in each T_C^{ij}, each element is divided to the sum of the elements of the corresponding row. For example, if every $T_C^{\propto}$ contains a set of $T_C^{\propto ij}$, $T_C^{\propto 11}$ is obtained from the normalization of T_C^{11}. With transposal matrix $T_C^{\propto}$.

$$T_C^{\alpha} = \begin{array}{c} \\ D_1 \\ \\ \\ D_i \\ \\ \\ D_n \\ \\ \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & & D_j & & D_n \\ c_{11}\ldots c_{1m_1} & \cdots & c_{j1}\ldots c_{jm_j} & \cdots & c_{n1}\ldots c_{nm_n} \end{array} \\ \begin{bmatrix} T_c^{\alpha 11} & \cdots & T_c^{\alpha 1j} & \cdots & T_c^{\alpha 1n} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha i1} & \cdots & T_c^{\alpha ij} & \cdots & T_c^{\alpha in} \\ \vdots & & \vdots & & \vdots \\ T_c^{\alpha n1} & \cdots & T_c^{\alpha nj} & \cdots & T_c^{\alpha nn} \end{bmatrix} \end{array} \tag{10}$$

$$d_{ci}^{11} = \sum_{j=1}^{m_1} t_{cij}^{11} \ , i = 1, 2, \ldots, m_1 \tag{11}$$

$$T_C^{\propto 11} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \cdots & t_{c1j}^{11}/d_{c1}^{11} & \cdots & t_{c1m1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_{ci}^{11} & \cdots & t_{cij}^{11}/d_{ci}^{11} & \cdots & t_{cim1}^{11}/d_{ci}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm11}^{11}/d_{cm1}^{11} & \cdots & t_{cm1j}^{11}/d_{cm1}^{11} & \cdots & t_{cm1m1}^{11}/d_{cm1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\propto 11} & \cdots & t_{c1j}^{\propto 11} & \cdots & t_{c1m1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\propto 11} & \cdots & t_{cij}^{\propto 11} & \cdots & t_{cim1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm1\,1}^{\propto 11} & \cdots & t_{cm1j}^{\propto 11} & \cdots & t_{cm1m1}^{\propto 11} \end{bmatrix} \tag{12}$$

Step 8: Generation of weighted super matrix: At this stage the matrix $T_D^{\propto}$ is multiplied by the matrix W(T_C^{α}). i.e. each $t_D^{\propto ij}$ is multiplied by its W_{ij} counterpart.

Step 9: Limiting the weighed Super Matrix: Limiting the weighted super-matrix by raising it to a sufficiently large power u until it converges and becomes a long-term stable super-matrix the global priority vector is obtained, which defines the influential weights from the criteria.

$$\lim_{Z\to\infty}(W^{\propto l})^Z, \qquad \lim_{Z\to\infty}(W^{\propto m})^Z, \qquad \lim_{Z\to\infty}(W^{\propto u})^Z \tag{13}$$

In the convergent final matrix, numbers indicate the relative weights of sub-factors, therefore, the measures can be prioritized according to their importance.

The final weight of the Criteria and the Sub-Criteria is show in Table 5.

Table 5. The weights and priorities of criteria and sub-criteria influencing the economic performance of manufacturing companies of Mazandaran province

FINAL WEIGHT AND PRIORITY		RELATIVE WEIGHT AND PRIORITY		CODE	RELATIVE WEIGHTS AND PRIORITIES OF MAIN CRITERIA	
(2)	0.0494	(1)	0.237	C11	0.2087 (1)	MANAGE SUPPLIERS (C1)
(24)	0.0391	(5)	0.187	C12		
(21)	0.0397	(3)	0.19	C13		
(11)	0.0408	(2)	0.195	C14		
(22)	0.0397	(4)	0.2	C15		
(23)	0.0395	(5)	0.195	C21	0.2023 (4)	PURCHASING AND PROCUREMENT SYSTEM (C2)
(13)	0.0406	(3)	0.201	C22		
(9)	0.0412	(1)	0.204	C23		
(10)	0.0412	(2)	0.204	C24		
(20)	0.0398	(4)	0.196	C25		
(19)	0.0399	(5)	0.196	C31	0.2035 (3)	HUMAN RESOURCE MANAGEMENT (C3)
(7)	0.0417	(1)	0.205	C32		
(18)	0.041	(4)	0.201	C33		
(16)	0.0403	(3)	0.198	C34		
(12)	0.0406	(2)	0.2	C35		
(8)	0.0413	(2)	0.202	C41	0.2045 (2)	ORGANIZATION AND LEADERSHIP (C4)
(15)	0.0405	(4)	0.198	C42		
(17)	0.0403	(5)	0.197	C43		
(6)	0.0419	(1)	0.205	C44		
(14)	0.0405	(3)	0.198	C45		
(1)	0.0502	(1)	0.261	C51	0.1918 (5)	INFORMATION TECHNOLOGY (C5)
(4)	0.0483	(3)	0.252	C52		
(5)	0.0441	(4)	0.23	C53		
(3)	0.0492	(2)	0.257	C54		

According to Table 5, the greatest weight is related to the manage suppliers which obtained the first priority (20.87%). The Lowest weight is related to the information technology which obtained the last priority (19.18%). Figure 2 shows the priorities of main criteria.

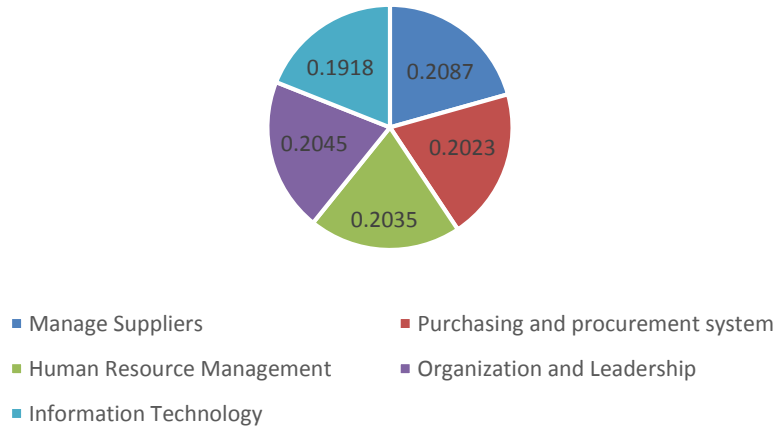

Figure 2. The chart of relative priorities of main criteria

4. Conclusion

The main purpose of the present study was identifying and ranking effective lean production factors on economic performance of production companies in Mazandaran province. According to previous studies and after survey, five main criteria and 24 sub-criteria were identified. The main criteria were: suppliers' management, purchase and procurement system, human resource organization, organization, leading, and IT. As a result of identifying these factors the authors were able to determine the primary objective of the study; identifying the effective factors of lean production on economic function of production companies. The second objective of the present study was determining the relation effects of the criteria on one another. To do so, the authors applied fuzzy DEMATEL technique. Results of this method revealed that factors like supplier management and organizing, and leading are those factors permeable and purchase and procurement, and human resources organizing and IT are among the effective factors. Thus, in order to improve economic function according to lean production indices, companies should invest in and purchase and procurement, and human resources organizing and IT that are among the effective factors. The ultimate purpose of the present study was calculating suitable weight for factors and sub-factors and prioritizing them applying mixed technique of fuzzy DEMATEL, based on fuzzy ANP. The results are as follows:

The stage of suppliers' management with the weight of 20.87 percent was the most important factor of lean production on economic function and IT with the weight of 20.35 percent was the least important factor. Regarding these results, managers in Mazandaran should pay specific attention to supplier management factor. Moreover, the results revealed that availability of information is the most important effective sub-factor on economic function of production companies that necessitates companies' production management in Mazandaran devise systems that provide them information concerning lean production factors online.

Other important recommendations are as following:

In human resource management:

- Considering training
- Designing job and organizing work
- Developing rewards policy
- Improving communication

In Information Technology:

- Creating a comprehensive information management system
- Updating intelligent information system
- Increasing Speed of information flow
- Deleting useless data

In purchase and procurement system:

- Implementing JIT
- Defining proper lead time

- Reducing extra orders
- Creating transportation policy, considering quality as a priority instead of price and evaluating the performance

In supplier management:

- Developing supplier selection criteria and categorization suppliers
- Controlling and assessing their quality assessment
- Evaluating their performance regularly
- In Leadership and Organizing
- Highlighting top management role and commitment as the key success factor
- Selecting the appropriate leadership style
- Engaging and developing of capable lean employees

Suggestions:

1. Examining challenges and obstacles in implementation of lean production in production companies and organization

2. As in the present study beside scientific methods, technical experts' views had significant effect on successful implementation of data analysis, the authors suggest in technical and critical areas of work form scientific circles comprised of experts to evaluate lean production function better and periodically but at long interval, continuously rectify the processes.

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