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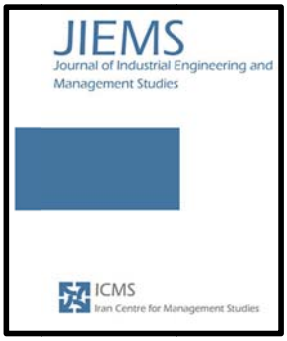

A Novel Approach in Robust Group Decision Making for Supply Strategic Planning in Manufacturing Networks

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Abstract

Long-term planning is a challenging process for dealing with problems in big industries. Quick and flexible process of responding to the existing variable requirements are considered in such problems. Some of important strategic decisions which should be made in this field are, namely the way that manufacturing facilities should be applied as well as assignment and design the system of delivery of orders. On the other hand, by using the small core and big network viewpoint in planning, such decisions should be made in a concentrated way. In this paper, a robust multi criteria group decision making model based on TOPSIS method is proposed, which evaluates the requirements of a real case study. In this regard, firstly important criteria in such environments would be determined. Secondly, using expert's opinions and statistical analysis methods the group multi criteria decision making model would be constructed.

Keywords: Design of strategic supply network; Group decision making; Multi criteria decision making, manufacturing networks, robust analysis

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1. Introduction

For a long-time, the basic supply, production, and distribution problems are considered as effective elements in the economic and industrial life cycle. In the recent years, the importance of these problems has a tremendous increasing rate and a great number of researches are done in this field. The mentioned problem is a function of a number of dependent sub-systems. Traditionally, such sub-systems were known as segregate activities. Currently, scientific communities and commercial world found the necessity of considering a holistic approach to deal with these various activities.

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The objective of this holistic approach is considering relationships and interacts among the mentioned activities. In the recent years, this field is quickly extended and many researches, which considered improvement of approaches to eliminate faults, are done in this area.

Due to increase in development of competitive space and global products market, organizations should use all of their efforts to optimize the supply chain of company to maintain their power of competition. By doing so, the ability of responding to various costumers' requirements in a short time and by using the minimum value of cost might be obtained. Therefore, supply chain management can be considered as a one of the most important parts in strategic management. Applying the systematic and holistic approach as well as considering the strategic factors in supply chain decisions can guaranty a long lifetime for companies in a competitive market.

Commonly, the criteria that are involved in the real world supply chain planning problems have conflict, such as minimizing the total cost of chain, maximizing the total value of ordering materials and parts, minimizing the number of failure units, minimizing the delay of product's delivery, and too name but a few. With respect to the mentioned discussions, supply chain planning model is a complex model. The reminder of paper is organized as follow: the literature review is presented in Section 2, the proposed methodology is described in Section 3, and analyse results of expert's opinions using the proposed approach is shown in Section 4.

2. Literature review

In this section the literature review of manufacturing based on network by focusing on flexibility and agility criteria is provided.

In the past, the manufacturing process was considered as a product, which has an application in low-technology approaches in downstream parts of industrial networks. In addition, inclination to specializing urged the other upstream parts of industrial networks to apply advanced techniques to achieve a proper position in the market. Moreover, compare to past years, the capital market require more resources to investment in capacity. Finally, a continuous stream is existed in extension of factors that compose manufacturing industrial networks. In the recent years, researches considered companies as an element of the network. The reasons for using this approach are advantages which are provided through information technology and data exchange, markets globalization, and inclination to specialization. These possibilities increase the availability of the abilities and resources of companies and prevent them from the classical logic of "construct or order" (Probert 1997; Cánez, Platts et al. 2000; Humphreys, McIvor et al. 2002).

In addition, the management world is faced with theories which are only effective for dealing with synchronous challenges in some of economic units. The mentioned theories lose their efficiency for a vast majority of other problems (Micklethwait and Wooldridge 1996; Fischer and Hafen 1997). Thinking of main skill (core competencies) and implication of lean production, agile production, and computer aided manufacturing, just in time production and sometimes a combination of the mentioned approaches are known as theories that answer to the related questions to supply chain management in the industrial networks. A prominent question is that the mentioned implications have a suitable efficiency concerning organizational networks? With respect to slight available information about failure of networks, Capello (1996) stated that the above mentioned idea have a logical reason. Thus, studying the requirement of industrial networks to existed theories with their self-characteristics synchronize with development of principal theories based on their unique specifications is of crucial important.

Concentrating on prominent abilities and out sourcing is the key of decision making for the case that value chain should focus on which area of production and must concentrate on which fields to

obtain the optimum performance (Friedrich 2000). In contrast to implication of out sourcing, the agile manufacturing process approach has a great inclination to use networks with weaker relationships than the past implications such as lean production (Nagel and Dove 1991; Burgess 1994; Katayama and Bennett 1999).

A great number of criteria for agile construct are proposed, among which responding, competition, flexibility, ability of rearrangement , fast manufacturing, information management, innovation, high activity, and power in market have a more importance (Vinodh 2011).

Table 1: evolution of organizational forms (Miles and Snow 1984)

Period	Market-Product Strategy	Structure	Inventor of applying	Core Activities and control Mechanism
1800	Unique products and services, local/regional market	Mediate	A majority of companies with limited activity area	Individual control and govern
1850	Limited providing of standard services or products	functional	Carnegie Steel	Central budget and plan
1900	Providing a broad spectrum of services and products. Internal/ international market	Multi sections	General Motors, Sears, Roebuck, Hewlett-Packard	Collective policies and profit share centers
1950	Standard and innovative services and products	Matrix	Many aerospace and electronics companies	Temporary teams and assignment tools for alternative resources such as internal markets, joined planning systems and etc.
2000	Design of providing services and products. Global various markets	Dynamic networks	International companies. Companies with worldwide consumers. Some of electronic and computer companies (such as IBM)	Mediate business trades and temporary structures with collective information systems as basic of harmony and trust

By considering the necessity to responding to consumers, increasing variation in market and requirements, etc., it is crystal clear that the agility of supply chain has a great importance in both scientific and empirical aspects. The most important components to evaluate agility of supply chain are as follow: stimulants, abilities, and ability creators. In addition, the most significant process which should be evaluated in supply chain is namely supplies, development, production, and distribution. In order to achieve agility a supply chain should have the following characteristics:

Sensitivity to market, speed, validation of data, new product introduction, cooperative design, consolidation process, use of technology tools, decrease the delay time, service level improvement, costs minimization, consumers satisfaction, quality improvement, mistrust minimization, trust extension, and decrease the resistance in confront with variation (Agarwal, Shankar et al. 2006).

These characteristics can be categorized into four main classes as follow (Christopher 2000): sensitive to market: ability of supply chain to imply and respond to real demand in market. Virtual space: using of information technology for sharing the information among purchasers and suppliers of virtual supply chain using developed electronic tools such as electronic data interchange (EDI) which improve the speed and clarity of the mentioned information. Consolidation process: cooperation among purchasers and suppliers, development of collective principals, collective systems and collective systems. Ability of being Network: This fact that a single company cannot achieve to success shows that a supply chain should be considered as a network.

3. Proposed methodology

In this study, thanks to the theoretical basics, some of the proposed criteria in the field of agile supply chain in manufacturing networks are discussed and judged through polling from experts. Then, a statistical analysis is conducted on the results and a summary of the outputs are applied in the proposed method to perform the group decision making. The features and steps of the proposed method would be described in the following sections.

After analysis of the questionnaire results, the weak points related to more important criteria would be determined and discussed based on SWOT (Strengths, weaknesses, opportunities, threats) methodology. The mentioned tool provides a suitable guideline for specifying the strategies of organization. Therefore, the proposed robust decision making method is constructed on the ground that important criteria, which are weak from internal situation aspect, should be located in the higher priority.

3.1 Data analysis

In this paper, the gathered opinions from experts about importance of some criteria ,namely sensitivity to market(internal and global), production speed, data and information validation, innovation, consolidation process, service level, cost, quality, flexibility, standardization, physical security, and information security are analysed using four choices Likert scale. In addition, to evaluate current internal situations, a five-choice scale has been applied. Furthermore, long term and medium term decisions related to supply and manufacturing chains including location, production planning, ordering, research and development, marketing and sale, transportation, and security decisions are provided for experts for making appropriate amendatory decisions. In this regard, the obtained results from analysis of SWOT in weak points, which can generate threat or opportunity, are used for a better analysis. In addition, variance analysis is applied for criteria evaluation.

3.2 The proposed robust decision making method

The proposed decision making method is developed based on TOPSIS, which is a useful method for such problems. The steps of this method are described in this section. TOPSIS method is proposed by Hwang and Yoon (1981) based on the more closeness to positive ideal and more distance from negative ideal. In order to achieve the best choice, TOPSIS method consider the following steps (Opricovic and Tzeng 2004):

1) Applying the Equation (1) to calculate the normalized matrix and make scores non scale.

$$r_{ij} = \frac{g_{ij}}{\sqrt{\sum_{j=1}^{m} g_{ij}^2}} \qquad (1)$$

where g_{ij} is the score of i^{th} choice in j^{th} criterion.

2) Using the following equation to calculate weighted normalized matrix.

$v_{ij} = w_i r_{ij}$; j= 1, . . . , m; I = 1, . . . , n; (2)

where W_i is the weight of j_{th} criterion.

3) Determining the negative ideal (A-) and positive ideal (A+) solutions. The score of each criterion in positive ideal solution is equal to the best available score of this criterion. In contrast, the scores of negative ideal solution are obtained using the worst available scores among choices. These statements can be shown as follow:

$$A^{+}=\{v_1^{+},\ldots, v_n^{+}\}=\{max_j(v_{ij})|i\epsilon I', min_j(v_{ij})|i\epsilon I''\}, \quad (3)$$

$$A^{-}=\{v_1^{-},\ldots, v_n^{-}\}=\{min_j(v_{ij})|i\epsilon I'', max_j(v_{ij})|i\epsilon I''\}; \quad (4)$$

Where I" involves criteria that should be minimized and I' involves criteria that should be maximized.

4) Using Equations (5) and (6) to calculate the distance from negative and positive ideal solution.

$$D_j^{+} = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^{+})^2} \quad (5)$$

$$D_j^{-} = \sqrt{\sum_{i=1}^{n}(v_{ij} - v_i^{-})^2} \quad (6)$$

5) Calculation of scores for each choice with respect to the principle that the distance from positive ideal as well as negative ideal is desirable for the model. Equation (7) is called closeness index and is considered as the score of each choices. The choice by more score has a preference to the others.

$$C_j^{+}=D_j^{-} / (Dj^{+}+D_j^{-}) \quad (7)$$

6) Ranking of choices

An important characteristic of this study is participation of many decision makers. Numerical values are calculated for the assigned scores by each expert to each criterion using Likert scale criteria, and then results are summarized as Table 2.

Table 2: Sample table for reports

Choice index	Importance		Current situation	
	Scores mean	Scores standard deviations	Scores mean	Scores standard deviations
Sensitivity to market				
Production speed				
. . .				
Information security				
Importance weight	2/6	1/6	2/6	1/6

Table 2 would be analysed using the steps of TOPSIS algorithm evaluate criteria in this industry,. Some notions are considered for constructing Table 2:

- The robustness is discussed in this analysis using involving the standard deviations of results, which is a criterion by negative direction. Hence, the choices that have a minimum value of the mentioned criterion have a preference to the others.

- Importance means demonstrate the sample mean among the obtained opinions. Since this criterion has a positive direction, the higher value will create better results.
- Current situation have a same calculation as importance mean, but have a negative direction. In fact, we should get a higher priority to a bad and crucial condition.
- Relative numerical importance or weight of each criterion is determined by opinion of analyser or decision maker.

At the end of this section, the main features of the proposed approach are summarized as follows:

- This study collects important criteria and managerial areas for strategic design of manufacturing networks with special focus on flexibility and agility.
- A new multiple attribute decision making method based on TOPSIS algorithm has been developed to consider multiple decision makers and robustness.
- Basic idea in SWOT methodology, as a well-grounded strategic planning approach, is included through the definition of criteria and their desired direction (negative or positive criteria).
- Deviations in DMs' responses for each criterion score have been studied to achieve robustness in results.
- Several statistical techniques including clustering, analysis of variance, and Tukey tests have been conducted on the decision matrix to analyse the questionnaire results.

In the next section, a real case study in a big network-based organization in Iran has been surveyed to illustrate the applicability of the proposed method.

4. Discussion and conclusion

In order to perform an opinion poll, appropriates experts with specialization in some areas such as industrial engineering and industrial management, or job experience in the field of planning for military industries, are selected. A master degree considered as the minimum educational level for the experts. The following equation is used to calculate the sample size.

$$n = \frac{Z_{\alpha/2}^{\ 2} \times S^2}{d^2} \tag{8}$$

Where

N: required sample size

$Z_{\frac{\alpha}{2}}$: Confidence level

d: estimation precision or maximum acceptable error

S: standard deviation of the past studies

The initial sample size for the mentioned analysis is 31. After calculation of required sample size, by %5 error and %5 precision, it is observed that required sample size in the worst condition is equal to15, which show the sufficiency of number of initial sample.

Before summarizing data and applying the proposed robust group decision making method, some of statistical features of results are described in this section.

4.1 Analysis of variance

Since enough number of samples is available, Analysis of Variance (ANOVA) is used to determine the significant differences among criteria and find the effects of each factor on responses. Figure 1 demonstrates the residual values have normal distribution.

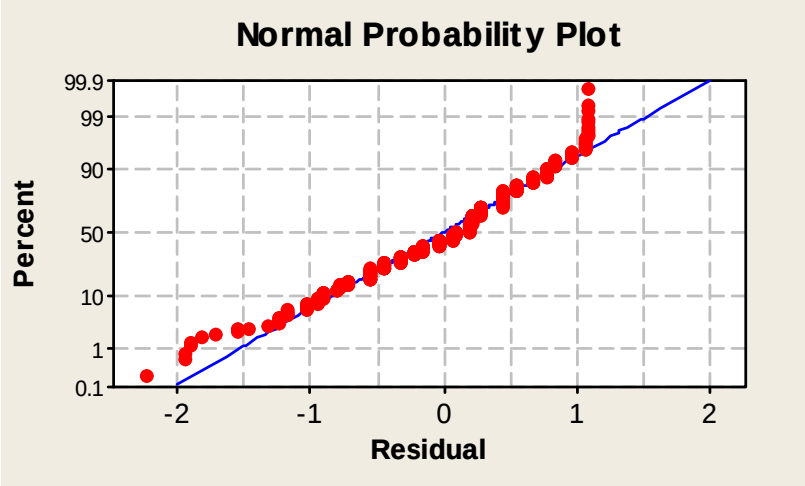

Figure 1: Normal probability plot for residual in ANOVA

The output of Minitab software is shown in the below (Table 3). With respect to these results, a significant difference among importance of criteria can be observed.

Table 3: Minitab output for ANOVA

Source	DF	SS	MS	F	P
Factor	11	34.933	3.176	7.35	0.000
Error	360	155.613	0.432		
Total	371	190.546			

Analysis of means for each groups shows that three criteria, namely 3, 8, and 12 are the best in term of importance mean. However, by considering the synchronize confidence intervals, which are proposed by software, some of the others of criteria could be chosen for the mentioned combination.

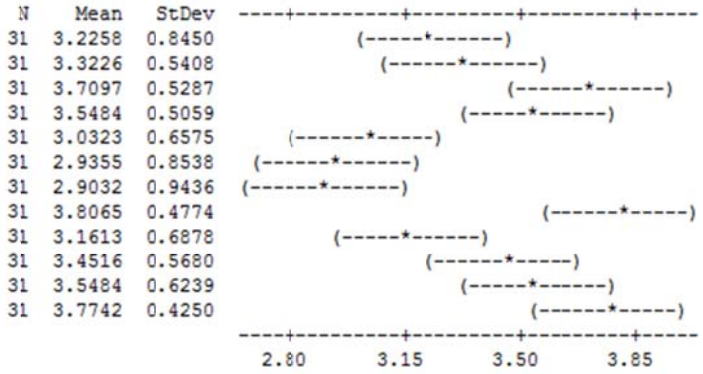

Figure 2: Confidence intervals report in MINITAB for ANOVA

Commonly, after rejecting the null hypothesis in variance analysis, the groups should be compared. In this regard, Tukey comparison method, which considers a %5 cumulative error to compare the various groups, is used for this study (Montgomery 2005).

The results are shown in both graphical and numerical forms. With respect to these results, a slight difference among importance of classified members in A to D from statistical aspect can be observed. These differences are not significant and can be ignored.

N	Mean	Grouping
31	3.8065	A
31	3.7742	A
31	3.7097	A B
31	3.5484	A B C
31	3.5484	A B C
31	3.4516	A B C D
31	3.3226	A B C D E
31	3.2258	B C D E
31	3.1613	C D E
31	3.0323	C D E
31	2.9355	D E
31	2.9032	E

Figure 3: Grouping the criteria with respect to their importance degrees

The criteria of each class are demonstrated in Table 3.

Table 4: Categorizing of decision making criteria with respect to importance

Class Criterion	A	B	C	D	E
Sensitivity to market(internal and international)		*	*	*	*
Production speed	*	*	*	*	*
Data and information validation	*	*			
Innovation	*	*	*		
Consolidation process			*	*	*
Service level				*	*
Cost					*
Quality	*				
Flexibility			*	*	*
Standardization	*	*	*	*	
Physical security	*	*	*		
Information security	*				

With respect to Table 4 and the output of Minitab software, the criteria that have a common letter, have a similar importance and they cannot be distinguished. In addition, for instance, in %95 confidence interval the quality criterion has a more importance than consolidation process, service level, cost, and flexibility criteria.

Another result from the Tukey test is that by increasing the number of classes, which some criteria belong to them, the diversity of their scores would be increased.

4.2 Criteria prioritization using robust group TOPSIS method

In every system, determining the weak points related to important criteria have a profound impact on design and improvement of the system. The proposed method summarizes the poll data and then identifies the weak points of important criteria. Moreover, the proposed method has a special attention to opinions concentration. Therefore, by considering the weight ratio 2 to 1 for mean against standard deviation, the obtained results by the proposed method can be seen in Table 5.

Table 5: Results of the proposed robust group TOPSIS method

Index choice	1	2	3	4	di+	di-	ci
1.	0.092	0.014	0.074	0.024	0.099	0.080	0.447
2.	0.095	0.056	0.081	0.068	0.056	0.120	0.684
3.	0.106	0.058	0.084	0.043	0.060	0.114	0.656
4.	0.101	0.061	0.132	0.051	0.029	0.155	0.843
5.	0.086	0.040	0.118	0.076	0.042	0.146	0.779
6.	0.084	0.013	0.108	0.039	0.079	0.116	0.595
7.	0.083	0.000	0.115	0.000	0.110	0.115	0.511
8.	0.108	0.065	0.094	0.061	0.041	0.133	0.764
9.	0.090	0.036	0.121	0.067	0.043	0.143	0.768
10.	0.098	0.053	0.098	0.045	0.051	0.121	0.702
11.	0.101	0.045	0.051	0.004	0.113	0.070	0.384
12.	0.107	0.073	0.000	0.024	0.142	0.080	0.361
Weight	0.333	0.167	0.333	0.167			
Positive ideal	0.108	0.073	0.132	0.076			
Negative ideal	0.083	0.000	0.000	0.000			

The choices and criteria of Table 5 are similar to the mentioned ones in Table 2.

Table 6: Organizational criteria prioritization based on the proposed method

Choice	Closeness index
Innovation importance	0.8425
Consolidation process importance	0.77893
Flexibility importance	0.76805
Quality importance	0.76444
Standardization importance	0.70208
Production speed importance	0.68362
Data and information validation importance	0.65604
Service level importance	0.59529
Cost importance	0.51114
Sensitivity to market(internal and international) importance	0.44673
Physical security importance	0.38377
Information security importance	0.36129

With comparison to initial results, which are obtained through statistical analysis on level of importance, some notions are considerable.

- By considering the weak points in addition to level of importance, data and information validation found a lower priority.
- Information security criterion, which was located in class-A in statistical analysis, obatined a lower strategic priority with respect to the acceptable internal status.

- Through applying the proposed method, flexibility in internal organization, which is one of the important agility criteria, obtained a higher priority.

Achieving to an adequate condition, by considering the results, requires appropriate decision making in the various levels. In this study, concentration is on long term and medium term decision. A great number of proposed methods are available in literature to fulfil this goal.

Strategic aspects of agility in supply chain can be summarized as follow:

- Powering the customers: the organizations determine and provide the services and products, which are exactly proper for customers.
- Cooperation's' development: creating virtual economic organizations, delegating, and even collaborating with competitors in order to achieve quick products delivery with minimum costs.
- Organizing against changes: to provide a merit in term of competition, an organization should be aware of their environment and gain the adoption ability.
- Adaption of persons and information: amalgamation of technology, personnel, and management with a suitable educational background can create innovative solutions.

In the next section, to validate the results of the proposed method, some of long time and medium time important decisions are analysed by experts.

4.3 Decision-support recommendations

In addition to the mentioned analysis in the last section, long time and medium time decisions are prioritized through polling. These results are shown in the follow.

```
Source   DF       SS     MS     F      P
Factor    6   26.765  4.461  9.07  0.000
Error   210  103.226  0.492
Total   216  129.991

S = 0.7011   R-Sq = 20.59%   R-Sq(adj) = 18.32%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
loc    31  2.9677  0.7063       (-----*-----)
prod   31  3.5806  0.5016                   (------*-----)
ord    31  2.9355  0.7718      (-----*------)
dev    31  3.7097  0.4614                        (-----*-----)
mark   31  2.8710  0.9217     (-----*-----)
tran   31  2.7742  0.7169  (-----*------)
sec    31  3.4194  0.7199                (-----*------)
                           -------+---------+---------+---------+--
                               2.80      3.20      3.60      4.00

Pooled StDev = 0.7011
```

Figure 4: Minitab report for the mean comparison among the decision types

In this study, the important decisions in the "level" column are location, production, ordering, research and development, marketing, transportation and security, respectively.

The results of variance analysis show a significant difference among the mentioned long time and medium time decisions in the available production environment. Almost it can be inferred that location, ordering, marketing and transportation decisions have a lower priority and production planning, research and development and security holding have a higher priority. The high priority of

research and development decisions shows that “trying to determine internal and external work environment” and “development to survive” have a great importance from expert’s points of view. Furthermore, a proper production planning creates a better control over estimated market and improves the service level.

5. Conclusion

Organizations of important industries require structured models for decision making. Such organizations have extensive supply networks with undetermined demands, which sometimes require significant changes in processes and rate of responding. In this study, a robust method based on TOPSIS decision making algorithm in a group form is proposed and its ability in military industry is evaluated. In addition to considering locational effect of responses, the proposed method can consider the deviation effect of responses on statistical analysis of decisions. In order to propose long time and medium time decision suggestions, the most important weak points are specified. In this regard, by interviewing with experts, important criteria related to such industries are determined and their related decisions are prioritized.

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