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Research Article

A hybrid fuzzy multiple attribute decision making approach for identification and ranking influencing factors on Bullwhip Effect in supply chain: real case of Steel industry

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Abstract

Bullwhip effect phenomenon is what reduces the efficiency of the supply chain. The effect occurs when demand changes in the supply chain face with a lot of volatility. So far, several key factors have been identified as causes of this phenomenon. Since the steel industry, is the basic one, its efficiency is of great importance. Therefore, in this study influencing factors on Bullwhip Effect in the industry will be identified and ranked so that by identifying the most important factors in its creation, proper decisions can be made to deal with this costly phenomenon. This study aims to review several reasons of the effect, identified by various authors. Then its impacts on the steel industry supply chain are mentioned. With views of experts from the steel industry, among the factors identified in the occurrence of the Bullwhip effect, by applying fuzzy Delphi method in the industry the most important ones are identified. The factors in previous phase, in the structure of SCOR model, are matched with the processes of this model then, ultimately, prioritized in order of importance with FANP method in aspect of SCOR criteria by the experts of the steel industry.

Keywords : Bullwhip Effect; Fuzzy ANP; SCOR; Steel industry; Supply Chain.

1 Introduction

The increase of competition created the situation in which customer needs and rapid responses to the market changes are the prerequirements of survival of organizations [5].

Therefore, some activities including cost reduction, increasing product quality, rapid fulfilment of customers needs and the like. are required. In the past years, the term supply chain management is formed to reduce costs by coordination among various sections of production and distribution of products and increase quality. Supply chain (SC) responsiveness implies its capabilities to provide product characteristics and service level according to customer requirements [13]. the Council of Supply Chain Management Professionals (CSCMP) defines supply chain management as: Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which

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can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies [6]. a comprehensive SCM includes all the members involved in its activities, from supplier to the final customer [11]. The importance of supply chain is increased as today there is no competition among the companies rather it is among supply chains [17]. Thus, firms should increase the total profitability of chain and identify the factors making effectiveness of supply chain problematic and reduce them. One of the most important factors on profitability and effectiveness of the supply chain is a phenomenon called Bullwhip Effect [16].

Bullwhip Effect is increasing demand changes in supply chain when we move to upstream levels [16]. As a whip, if we make a little swing at the front of whip, this swing at the end of whip is increases more than the initial force [22]. This fluctuation is created in three information, physical and financial aspects in supply chain and the result is the lack of coordination and costs in the entire chain as well as customer dissatisfaction. It is worth to mention that bullwhip effect is not eliminated and its costs effects are reduced only by managing it [3]. Today, the importance of bullwhip effect is great as it is recognized as one of the criteria of supply chain performance evaluation [14]. Being aware of bullwhip causes helps organizations and supply chains to take some policies with the aim of reduce its occurrence and harmful effects. These factors are of different importance in various industries. Now, Steel industry is one of the important and basic industries in the world, particularly in Iran. The development and progress of this industry can be considered as one of the main criteria of communities industrialization. Since steel is a raw material in most of products (e.g. building, car, furniture and etc.), the inefficiency of supply chain in this industry can have negative influence on other relevant industries. Therefore, steel industry and specifically west Asia steel company are evaluated in this study, so that by identifying the most important factors in its creation, proper decisions can be made to deal with this costly phenomenon. west Asia steel company was established to attempt private investors and rely on senior managers experience on Folad Mobarakeh corporation in 2004 to implement the project of cold rolling to 550000 tons per year with a final thickness of 0.18 to 3 mm, width 600 to 1700 mm and weight of each coil 6 to 30 tones with international standards, in an area of 53 hectares and 40000 square meter of foundation in Qom (30 km to Delijan). The main product of this corporation is consumed in industries such as automotive, appliance, covering buildings, painted sheets, galvanized sheets, box for packaging (such as industrial oil paint), cannery, etc. At first, the influencing factors on bullwhip in supply chain of steel industry are identified. These factors are compared with the processes of SCOR model as supply chain reference model and are ranked by fuzzy ANP and criteria of SCOR model in terms of importance.

2 Literature Review

The first academic study on bullwhip effect was performed by Forrester (1961). Most of the operation management researchers have been familiar with the bullwhip effect through Forrester work in the book Classic Planning and Control written by Buffa and miller (1979, 411-418.PP). By empirical study, Forrester showed that the demand fluctuation seen by manufacturers is much more than the fluctuation in consumer demand and it is increased stage by stage along with supply chain. Sterman (1989) presented simulation after Forrester called Beer Game Distribution. This simulation as a great tool indicates the impact of different views to supply chain on the efficiency of supply chain. This phenomenon, called Forrester effect, shows the variance of orders given to suppliers is more than the variance of orders taken from buyers and customers [24].

This effect was called Bullwhip Effect by Lee et al., (1997) due to the fluctuation behavior of demand moving along the supply chain path. The effect imposing heavy costs on system, as Lee defined the bullwhip effect, is as: The bullwhip effect occurs when the demand order variability in the supply chain are amplified as they moved up the supply chain [15]. In the study done by Lee, four main causes have been identified for this phenomenon as followings:

1- Demand forecast updating
2- Order batching
3- Price fluctuation
4- Rationing and shortage gaming

Sucky (2009) divided researches on the bullwhip effect into six general categories: (i) papers aiming at a quantification of the bullwhip effect, (ii) works focusing on analyzing and identifying the causes of the bullwhip effect, (iii) studies observing the bullwhip effect in some industries or in numerous examples from individual products and companies, (iv) papers addressing methods for reducing the bullwhip effect, (v) works focusing on simulating the system behaviour and (vi) papers focusing on experimental validation of the bullwhip effect [20].

Chen et al. (2000) quantified and derived a lower bound for the bullwhip effect in a simple supply chain for two cases of forecasting methods: moving average and exponential smoothing. Dejonckheere et al. (2003) proposed a control theory approach for measuring bullwhip effect and suggested a new general replenishment rule that can reduce variance amplification significantly. Disney and Towill (2003) introduced an ordering policy that results in taming bullwhip effect. Zhang (2004) considered three forecasting methods for a simple inventory control system and presented three measures for bullwhip effect based on three forecasting methods [20]. Geary et al. (2006) detected 10 published causes of bullwhip, all of which are capable of elimination by re-engineering the supply chain and suggested some evidence on the present health of a family of supply chains, and pinpoint much good practice [21]. Nepal et al. (2012) presented an analysis of the bullwhip effect and net-stock amplification in a three echelon supply chain considering step-changes in the production rates during a product's life-cycle demand. Using a simulation approach, the analysis was focused around highly complex and engineered products, which have relatively long production life cycles and require significant capital investment in manufacturing. Buchmeister et al. (2014) simulated a simple three-stage supply chain using seasonal and deseasonalized time series of the market demand data in order to identify, illustrate and discuss the impacts of different level constraints on the bullwhip effect. The results were presented for different overall equipment effectiveness (OEE) and constrained inventory policies [20].

The causes of the bullwhip are double: operational and behavioral causes. The operational causes of the bullwhip include: demand forecasting updating, batch ordering, price fluctuation, Shortage gaming, lead time, inventory policy, procurement policy, inaccurate system of order, lack of transparent, number of echelons, multiplier effect, lack of the synchronization, erroneous perception of the feedback, optimization of people of the country without global vision, process of company, limits of capacity. While the behavioral cause include: neglecting the delay by making decisions of order, lack of study or training, been afraid by the empty actions. The root of all the causes is the lack of coordination among the members of supply chain [8].

Another researcher conducted studies regarding the causes of bullwhip effect in supply chains. that the results are briefly shown in Table 1.

Based on the identified factors by various researchers, these factors in two operational and behavioral factors are the bases of conceptual model of the study (Figure 1). Later, these factors are refined by fuzzy Delphi method by experts of steel industry in West Asia Steel Company. Then, they are ranked in terms of importance by fuzzy ANP and SCOR model criteria. Chen et al. (2000) quantified and derived a lower bound for the bullwhip effect in a simple supply chain for two cases of forecasting methods: moving average and exponential smoothing. Dejonckheere et al. (2003) proposed a control theory approach for measuring bullwhip effect and suggested a new general replenishment rule that can reduce variance amplification significantly. Disney and Towill (2003) introduced an ordering policy that results in taming bullwhip effect. Zhang (2004) considered three forecasting methods for a simple inventory control system and presented three measures for bullwhip effect based on three forecasting methods [20]. Geary et al. (2006) detected 10 published causes of bullwhip, all of which are capable of elimination by re-engineering the supply chain and suggested some evidence on the present health of a family of supply chains, and pinpoint much good practice [21]. Nepal et al. (2012) presented an analysis of the bullwhip effect and net-stock amplification in a three echelon supply chain considering step-changes in the production rates during a product's life-cycle demand. Using a simulation approach, the analysis was focused around highly complex and engineered products, which have relatively long production life cycles and require significant capi-

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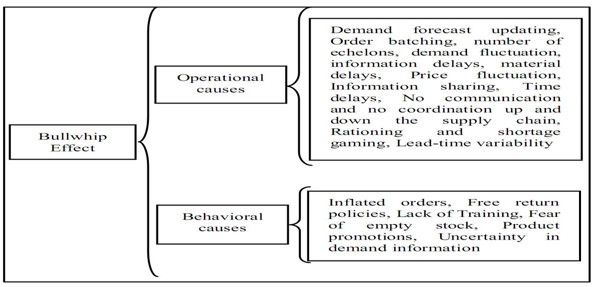

Figure 1. The basic conceptual model

Figure 1

Fuzzy Linguistic Variables

The fuzzy linguistic variable is a variable that reflects different aspects of human language. Its value represents the range from natural to artificial language. When the values or meanings of a linguistic factor are being reflected, the resulting variable must also reflect appropriate modes of change for that linguistic factor. Moreover, variables describing a human word or sentence can be divided into numerous linguistic criteria, such as equally important, moderately important, strongly important, very strongly important, and extremely important, as shown in Figure 2; definitions and descriptions are shown in Table 2. For the purposes of the present study, the 5-point scale (equally important, moderately important, strongly important, very strongly important and extremely important) is used.

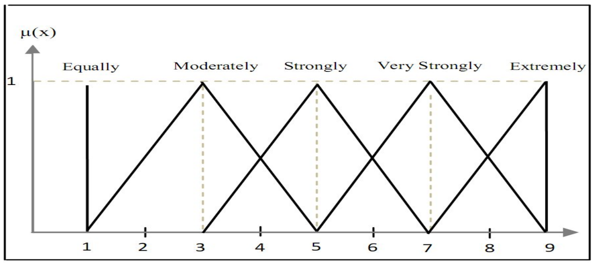

Figure 2. fuzzy membership function for linguistic variable attributes [9]

Figure 2

3 Study Methodology

As it was said, most of the researchers investigated the causes of bullwhip effect in supply chain (Table 1) that these factors are the bases of the present study. Then, these factors are refined in steel industry with the experts of this industry in West Asia Steel Company by Fuzzy Delphi method. As having access to these experts is not easy, judgment sampling method (as limited class of people have the required information) is applied and 15 experts of steel industry are considered.

3.1 Fuzzy Delphi method

Fuzzy Delphi method was introduced by Kaufmann and Gupta in 1980s [4]. It is a combination of fuzzy set theory and Delphi technique [18]. The fuzzy Delphi method is an analytical method for decision making which incorporates fuzzy theory in the traditional Delphi method.

First, the selected components are sent to the 15 members of experts group in West Asia Steel Company. Their approval regarding each of components is received and the proposed corrections are concluded.

Based on the results of first stage and after holding meetings with experts, some corrections as adding or omitting of components are made and in the next stage of survey, besides applying required changes in cause of bullwhip effect, the second questionnaire is provided and sent with the previous views of each person and their difference with the mean of the views of others to the experts again. After survey of second stage, based on the presented views in the first stage and comparing them with the results of the second stage, whereas the difference between two stages is less than threshold limit $(0, 0.1)$, the survey process is stopped [4]. Threshold limit is computed by the following equation:

$$s(A_{m2}, A_{m1}) = \left|\frac{1}{3}\Big[(a_{m21} + a_{m22} + a_{m23}) - (a_{m11} + a_{m12} + a_{m13})\Big]\right| \quad (3.1)$$

Based on the results of fuzzy Delphi method, model 1 of study is presented in two general categories of operational and environmental factors as shown in Figure 3:

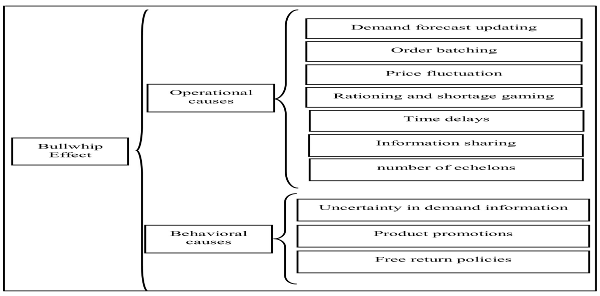

Figure 3. Categories the causes of bullwhip effect (model 1)

Figure 3

3.2 Fuzzy ANP method

Based on the results of fuzzy Delphi method and identification the factors that impact on bullwhip effect in supply chain of steel industry (Figure 3), these factors will be ranked in steel industry. By identification of more important factors, the main focus of the industry will be on the important factors to reduce bullwhip effect.

The Analytic Network Process (ANP) method is performed in six steps:

1- Network construction

2- Determining correlation links

3- Pairwise comparison

4- Calculation of inconsistency rate

5- Calculation of components (Criteria and Factors) weight

6- Factors ranking

To determine the importance of the factors that impact on bullwhip effect, some criteria to rank these factors is needed. To do this, in present study used SCOR model criteria as supply chain reference model for the ranking and they are shown in Table 4.

In the execute stage of fuzzy ANP technique, steel industry experts judge about the importance of the factors that impact on bullwhip effect based on four above criteria and metrics considered for each criteria.

Each of the factors affecting on bullwhip effect as shown in model 1 as well as Table 5 is dedicated to supply chain processes in SCOR model as Plan, Source, Make and Deliver. This is done to show the position of each of the factors in a standard supply chain. To continue, FANP method stages are explained based on mentioned six stages:

3.3 Network construction

By considering the goal, criteria and factors extracted in the previous sections, ANP network structure is designed as shown in Figure 4.

3.4 Determining correlation links.

The correlation between the factors (factors affecting on bullwhip effect) is based on the studies of Haejoong [12]. Figure 4 shows the network structure of ANP model with correlation links. According to ANP model of the study, general

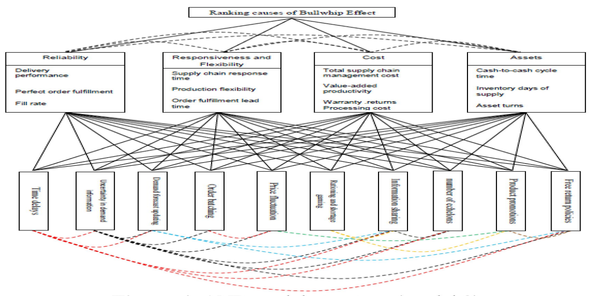

Figure 4. ANP model structure (model 2)

Figure 4

Table 1: Causes of bullwhip effect

Factors	Reference
Demand forecast updating, Order batching Price fluctuation, Rationing and shortage gaming, Rationing and shortage gaming	[15]
Demand forecast updating, Order batching, Material delays, Information delays, Purchasing delays, Number of echelons	[19]
Uncertainty in demand information, Nonlinear delayed information, Unstable timing due to incorrect information, Demand fluctuation, Multiplicity of organizational	[25]
Demand forecast updating, Order batching Price fluctuation, Rationing and shortage gaming	[15]
Forecast errors, Overreaction to backlogs, Lead-time variability, No communication and no coordination up and down the information and material flow, Batch ordering (larger orders result in more variance), Shortage gaming, price fluctuations, Product promotions, Free return policies, Inflated orders	[2]
Lack of Training Fear of empty stock	[26] [7, 23]

Table 2: Definition and membership function of fuzzy number [9]

Fuzzy number	Linguistic variable	Triangular fuzzy number	Fuzzy reciprocal
1	Equally important	$(1, 1, 1)$	$(1, 1, 1)$
3	Moderately important	$(1, 3, 5)$	$(1.5, 1.3, 1)$
5	Strongly important	$(3, 5, 7)$	$(1.7, 1.5, 1.3)$
7	Very strongly important	$(5, 7, 9)$	$(1.9, 1.7, 1.5)$
9	Extremely important	$(7, 9, 9)$	$(1.9, 1.9, 1.7)$

Table 3: Difference between the first and second stage survey of expert views

Stage	Factors	First stage	Second stage	Difference the first and Sec stage
1	Demand forecast updating	0.68	0.67	0.01
2	Order batching	0.48	0.51	0.03
3	Price fluctuation	0.77	0.82	0.05
4	Rationing and shortage gaming	0.62	0.64	0.02
5	Uncertainty in demand nformation	0.72	0.71	0.02
6	Number of echelons	0.68	0.7	0.02
7	Information sharing	0.81	0.85	0.04
8	Product promotions	0.60	0.61	0.01
9	Time delays	0.63	0.62	0.01
10	Free return policies	0.65	0.63	0.02

structure of super matrix showing the relations of criteria and factors is shown as followings:

$$W = \begin{pmatrix} 0 & 0 & 0 \\ W21 & W22 & 0 \\ 0 & W32 & W33 \end{pmatrix} \qquad (3.2)$$

3.5 Pairwise comparison

As the network structure of the model and internal relations of factors are explained in the previous section, the pairwise comparison matrices are designed and presented to 7 experts of steel

Table 4: SCOR's level 1 metrics [22]

External, customer facing			Internal facing
Reliability	**Responsiveness and Flexibility**	**Cost**	**Assets**
Delivery performance	Supply chain response time	Total supply chain management cost	Cash-to -cash cycle time
Perfect order fulfilment	Production flexibility	Value-added productivity	Inventory days of supply
Fill rate	Order fulfilment lead time	Warranty returns Processing cost	Asset Asset

Table 5: Causes of bullwhip effect and SCOR model processes [12]

	Causes of Bullwhip Effect	**SCOR process**
Behavioral causes	Uncertainty in demand information	Plan
	Product promotions	Source
	Free return policies	Deliver
Operational causes	Demand forecast updating	Plan
	Order batching	Source
	Price fluctuation	Plan
	Rationing and shortage gaming	Deliver
	Time delays	Plan-Source-Deliver
	Information sharing	Plan
	number of echelons	Plan

Table 6: Random Indexes

Matrix size	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI^m	0	0	0.48	0.79	1.07	1.19	1.28	1.34	1.37	1.40	1.41	1.44	1.45	1.49	1.49
RI^g	0	0	0.17	0.26	0.35	0.38	0.40	0.41	0.43	0.44	0.45	0.47	0.46	0.48	0.48

Table 7: Criteria pairwise comparison matrix according to the goal

Goal	Reliability	Responsivenes and Flexibility	Cost	Assets	W
Reliability	$(1, 1, 1)$	$(0.33, 0.47, 3.96)$	$(1.68, 2.72, 3.96)$	$(1, 1.36, 1.58)$	0.30
Responsiveness and Flexibility	$(1.36, 2.09, 3.04)$	$(1, 1, 1)$	$(2.33, 3.39, 4.26)$	$(0.93, 2.01, 3.31)$	0.44
Cost	$(0.2520.36, 0.59)$	$(0.23, 0.29, 0.42)$	$(1, 1, 1)$	$(0.34, 0.50, 1.04)$	0.01
Assets	$(0.63, 0.73, 1)$	$(0.30, 0.49, 1.07)$	$(0.95, 1.96, 2.93)$	$(1, 1, 1)$	0.22
CR^m	0.011	CR			
CR^g	0.035				

	$\sum l = 14.357$	$\sum m = 20.435$	$\sum u = 27.941$
		$[\sum \sum M_{ij}]^{-1}$	
	0.036	0.049	0.070
	L	M	U
$\sum MK_1$	4.013	5.575	7.280
$\sum MK_2$	5.630	8.497	11.577
$\sum MK_3$	1.828	2.170	3.073
$\sum MK_4$	2.886	4.193	6.010

	1	m	U
S_1	0.144	0.273	0.507
S_2	0.202	0.416	0.806
S_3	0.065	0.106	0.214
S_4	0.103	0.205	0.419

$V(S_1 \geq S_2) = 0.681$	$V(S_1 \geq S_3) = 1$	$V(S_1 \geq S_4) = 1$
$V(S_2 \geq S_1) = 1$	$V(S_2 \geq S_3) = 1$	$V(S_2 \geq S_4) = 1$
$V(S_3 \geq S_1) = 0.397$	$V(S_3 \geq S_2) = 0.039$	$V(S_3 \geq S_4) = 0.528$
$V(s_4 \geq S_1) = 0.803$	$V(S_4 \geq S_2) = 0.0508$	$V(S_4 \geq S_3) = 1$

	W'	W	
$V(S_1 \geq S_2, S_2, S_4)$	0.681	0.306	W_1
$V(S_2 \geq S_1, S_3, S_4)$	1	0.449	W_2
$V(S_3 \geq S_1, S_2, S_4)$	0.039	0.017	W_3
$V(S_4 \geq S_1, S_2, S_3)$	0.508	0.228	W_4
$\sum W'$	2.228		

Table 8: Criteria weight according to goal matrix (W21)

Criteria	Weight
Reliability	0.306
Responsiveness and Flexibility	0.449
Cost	0.017
Assets	0.228

industry in West Asia steel Company (based on judgment sampling method) as well as the next stage.

Table 9: Internal weight of criteria matrix (W22)

	Reliability	Responsiveness and Flexibility	Cost	Assets
Reliability	0	0.486	0.268	0.354
Responsiveness and Flexibility	0.488	0	0.365	0.496
Cost	0.075	0.209	0	0.149
Assets	0.437	0.305	0.367	0

Table 10: Total weight of criteria matrix (Wcriteria)

Criteria	Weight
Reliability	0.304
Responsiveness and Flexibility	0.269
Cost	0.151
Assets	0.277

Table 11: Alternatives weight according to criteria matrix (W32)

	Reliability	Responsiveness and Flexibility	Cost	Assets
Time delays	0.151	0.165	0.126	0.155
Uncertainty in demand information	0.154	0.178	0.122	0.118
Demand forecast updating	0.171	0.175	0.101	0.113
Order batching	0.117	0.115	0.183	0.140
Price fluctuation	0.054	0.024	0.003	0.018
Rationing and shortage gaming	0.011	0.018	0.008	0.048
Information sharing	0.163	0.174	0.133	0.146
Number of echelons	0.157	0.130	0.128	0.171
Product promotions	0.003	0.003	0.182	0.003
Free return policies	0.019	0.018	0.013	0.063

3.6 Calculation of inconsistency rate

After performing pairwise comparison and achieving pairwise comparison matrix, to be sure of the validity and consistency of collected data, inconsistency rate is calculated and in this study Gogus and Boucher method is applied for this purpose. In this method, at first fuzzy triangular matrix is divided into two matrices of middle numbers and geometric mean of upper and lower limits of triangular numbers. In the next stage, the weight vector of each matrix is calculated by Saaty method as following:

$$w_i^m = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ijm}}{\sum\limits_{i=1}^{n} a_{ijm}} \quad \text{that} \quad w^m = [w_i^m] \tag{3.3}$$

$$w_i^g = \frac{1}{n}\sum_{j=1}^{n}\frac{\sqrt{a_{iju}\cdot a_{ijl}}}{\sum\limits_{i=1}^{n}\sqrt{a_{iju}\cdot a_{ijl}}} \quad \text{that} \quad w^g = [w_i^g] \tag{3.4}$$

The biggest eigenvalue for each matrix is calculated by the following equation:

$$\lambda_{\max}^m = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ijm}(\frac{w_j^m}{w_i^m}) \tag{3.5}$$

$$\lambda_{\max}^g = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{a_{iju}\cdot a_{ijl}}(\frac{w_j^g}{w_i^g}) \tag{3.6}$$

Table 12: Internal weight of alternatives matrix (W33)

	Time delays	Uncertainty	Demand forecast updating	Order batching	Price
Time delays	0	0.135	0	0	0
Uncertainty in demand information	0.233	0	0.461	0.343	0.525
Demand forecast updating	0.259	0.284	0	0	0
Order batching	0	0.107	0	0	0.299
Price fluctuation	0	0.106	0	0.657	0
Rationing and shortage gaming	0	0	0	0	0
Information sharing	0.214	0.239	0.495	0	0
number of echelons	0.240	0.110	0	0	0
Product promotions	0	0	0	0	0.176
Free return	0.055	0.018	0.044	0	0
Time delays	0	0.183	0.170	0	0.242
Uncertainty in demand	0	0.267	0.413	0	0.150
Demand forecast	0	0.281	0	0	0.282
Order batching		0	0	0	0
Price fluctuation	0	0	0	0.339	0
Rationing and shortage	0	0	0	0.429	0
Information sharing	0.621	0	0.417	0	0
Number of echelons	0	0.268	0	0	0
Product promotions	0.379	0	0	0	0.325
Free return policies	0	0	0	0.232	0

Then, consistency rate is computed by the following equation:

$$CI^m = \frac{(\lambda^m_{\max} - n)}{(n-1)} \quad (3.7)$$

$$CI^g = \frac{(\lambda^g_{\max} - n)}{(n-1)} \quad (3.8)$$

Finally, to compute inconsistency rate (CR), CI index is divided by random index (RI)(Table 6). If the value is lower than 0.1, the matrix is consistent and validated [10].

3.7 Calculation of components weight

After being sure of consistency of pairwise comparison the views of experts via geometry mean method is collected as the following equation have.

$$\tilde{z}_{ij} = \Big(\sqrt[k]{l_1 \times l_2 \times \ldots \times l_k},\ \sqrt[k]{m_1 \times m_2 \times \ldots \times m_k},\ \sqrt[k]{u_1 \times u_2 \times \ldots \times u_k}\Big) \quad (3.9)$$

Then, the components weight is computed. In present study, Extent Analysis (EA) method is used with the purpose of finding the weight

Table 13: Total weight of alternatives matrix (Walternative)

	Reliability and Flexibility	Responsiveness	Cost	Assets
Time delays	0.082	0.082	0.066	0.087
Uncertainty in demand information	0.293	0.274	0.231	0.265
Demand forecast updating	0.134	0.147	0.108	0.132
Order Batching	0.033	0.026	0.014	0.018
Price fluctuation	0.094	0.095	0.195	0.106
Rationing and shortage gaming	0.001	0.001	0.078	0.001
Information sharing	0.226	0.230	0.165	0.219
Number of echelons	0.097	0.106	0.079	0.089
Product promotions	0.020	0.017	0.008	0.042
Free return policies	0.019	0.021	0.056	0.016

of criteria and alternatives. Extent Analysis (EA) method has been presented by a Chinese researcher Chang. The applied numbers in this method are fuzzy triangular numbers. In EA method, Sk as a triangular number for each of rows of pairwise comparison matrix is computed as followings:

$$s_i = \sum_{j=1}^{m} M_{gi}^{i} \otimes \Big[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\Big]^{-1}$$

$$\sum_{j=1}^{m} M_{gi}^{i} = \Big(\sum_{j=1}^{m} 1_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \Big(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\Big)$$

$$\Big[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\Big]^{-1} = \Big(\frac{1}{\sum_{i=1}^{n} u_i}, (\frac{1}{\sum_{i=1}^{n} m_i}, (\frac{1}{\sum_{i=1}^{n} l_i}\Big)$$

Where g indicates number of row and i & j show alternatives and criteria. In EA method, after calculation of Sk, its magnitude degree should be achieved. Generally, if M1, M2 are two triangular fuzzy numbers, magnitude degree $M1$ to $M2$ denoted by $V(M1 > M2)$ is defined as followings:

$$V(MI \geq M2) = \begin{cases} 0 & ml \geq m2 \\ 0 & l2 \geq ul \\ Hgt(M1 \cap M2) & otherwise \end{cases} \tag{3.10}$$

and

$$Hgt(M1 \cap M2) = \frac{u_1 - l_2}{(u_1 - l - 2) + (m_2 - m_1)}$$

The magnitude of a triangular fuzzy number of k triangular fuzzy numbers is achieved by the following equation:

$$V(M1 \geq M2, \ldots, Mk) = \min[V(M1 \geq M2), \ldots, V(M1 \geq Mk)] \tag{3.11}$$

In EA method, to calculate the weight of criteria in pairwise comparison matrix, we have:

$$W'(Xi) = \min\{V(Si \geq Sk)\} \quad , \quad k = 1, 2, \ldots, n, \; k \neq i \tag{3.12}$$

Thus, the weight vector of criteria is as the followings:

$$W' = [W'(c1), W'(c2), \ldots, W'(cn)]^T \tag{3.13}$$

and it is non-normalized coefficient vector of fuzzy ANP. The calculations of this method are presented for a matrix as followings (Table 7): By calculation of the weight of all pairwise comparison matrixes, the following matrixes are computed as: Criteria weight according to goal

(W21), internal weight of criteria (W22), total weight of criteria, the weight of alternatives according to criteria (W32), internal weight of alternatives (W33) and total weight of alternatives: According to (W21) and (W22) matrixes, the total weight of criteria matrix (Wcriteria) is calculated as follows :

$$W_{criteria} = W22 \times W21 \quad (3.14)$$

According to (W32) and (W33) matrixes, the total weight of alternatives matrix (Walternative) is calculated as follows :

$$W_{Alternative} = W33 \times W32 \quad (3.15)$$

After combining the total weight of criteria (Table 10) and total weight of alternatives (Table 11), the final weight of alternatives by which the factors (alternatives) will be ranked is achieved (Table 11).

3.8 Prioritization of factors

Table 11 indicates the final weight of factors by which the judgment of steel industry experts in West Asia Steel Company is extracted. Based on these weights, we can prioritize the effectiveness of the factors that impact on bullwhip effect in supply chain of steel industry. Then, the judgment of steel industry experts in terms of importance in West Asia Steel Company is ranked as Table 12.

4 Discussion and Conclusion

In this study, the influencing factors on bullwhip effect in supply chain are first identified. Then the factors refined with the views of experts in the steel industry through fuzzy Delphi Method and finally ranked by ANP method. As shown (Table 15), the factors that influence on bullwhip effect in steel industry are ranked based on importance. According to this prioritization and comparing these factors with the processes of SCOR model as shown in Table 14, more important processes of SCOR model can be identified in supply chain of steel industry. Figure 5 shows the contribution of each process of SCOR model according to the factors affecting on bullwhip effect in supply chain of steel industry. As shown in Figure 5, the most important factors affecting on bullwhip effect in steel industry are dedicated to

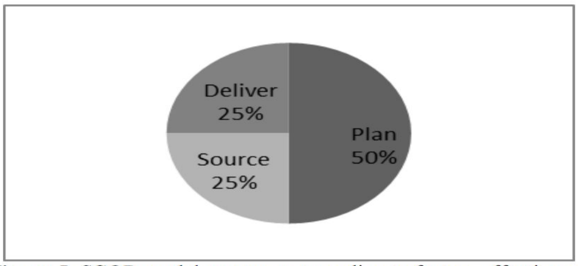

Figure 5. SCOR model processes according to factors affecting on Bullwhip Effect in steel industry supply chain

Figure 5

Plan process in SCOR processes. The decision makers in this industry should consider this process and the factors with high priority in creating bullwhip effect in this industry. For further studies, researchers can consider the amount of the influence of each of factors on bullwhip effect.

Based on the results of prioritization (Table 13), it can be found out which factors have the highest impact on bullwhip effect in steel industry and most important of them are including: Uncertainty in demand information, Information sharing, Demand forecast updating, price fluctuations, number of echelons and so on.

According to these priorities, by focusing on more important factors the decision makers in the steel industry can reduce the bullwhip effect. For this purpose, some proposals based on the results of the study will be presented:

uncertainty in demand information arises from invalid and inappropriate information resources, so by focused demand information, each echelon of supply chain will have access to factual information of customer demand and reduce uncertainty in demand information. Alsudairi states, by integrating BI (Business Intelligence) with Text and Web analytics, organizations can derive better customer demand information and KPI(Key Performance Indicators) along the Supply chain so that it can be used to mitigate the Bullwhip effect [1].

information sharing can be improved by integration information flow for example with the use of EDI (Electronic Data Interchange) and POS (point of sale) that reduces the information lead time in the order process.

demand forecast updating is another important factor influencing bullwhip effect by placing a single source for forecasting demand during supply chain which in turn can reduce its negative impact on the effect.

Table 14: Final weight of alternatives according to goal matrix by FANP method

Factors	Weight
Time delays	0.081
Uncertainty in demand information	0.271
Demand forecast updating	0.133
Order batching	0.024
Price fluctuation	0.113
Rationing and shortage gaming	0.013
Information sharing	0.216
number of echelons	0.095
Product promotions	0.023
Free return policies	0.024

Table 15: Ranking the factors that impact On Bullwhip Effect in steel industry supply chain using FANP

Priority	Factors	Weight
1	Uncertainty in demand information	0.271
2	Information sharing	0.216
3	Demand forecast updating	0.133
4	Price fluctuation	0.113
5	number of echelons	0.095
6	Time delays	0.081
7	Order batching	0.024
8	Free return policies	0.024
9	Product promotions	0.023
10	Rationing and shortage gaming	0.013

price fluctuations can be controlled by forward purchasing goods and materials with future delivery.

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