



## Role of Time in Agile Supply Chain

J. Jassbi, N. Pilevari\*, & M. Garmaki

*Javad Jassbi*, Department of Industrial Management, Faculty of Management & Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran. [Jassbi@srbiau.ac.ir](mailto:Jassbi@srbiau.ac.ir)

*Nazanin Pilevari* Department of Industrial Management, College of Management and Accounting, Yadegar-e-Imam Khomeini(RAH) Branch, Islamic Azad University, Tehran, Iran. [n\\_pilevari@yahoo.com](mailto:n_pilevari@yahoo.com)

*Mahdi Garmaki*, Department of Management, Alborz Institute, Ghazvin, Iran. [mahda.garmaki@gmail.com](mailto:mahda.garmaki@gmail.com)

### KEYWORDS

Agile supply chain (ASC),  
Supply Chain Management,  
ANFIS

### ABSTRACT

*Nowadays, in turbulent and volatile global markets an Agile Supply Chain (ASC) is frequently considered as a dominant competitive advantage for survival. To achieve the competitive advantage, companies must align with suppliers and customers to streamline operations, as well as agility beyond individual companies. There are many definitions and models about agile supply chain and most of them have emphasized capabilities and enablers, and their sub attributes, as two critical factors, but regardless of time and its effect on the main attributes. This paper tries to present the role of time on predicting the agility of supply chain, by studying effect of intervention time on enablers and eventually predict the progress trend of agility in supply chain. This article follows our previous research which is present the model of agility in supply chain management by ANFIS method and has been published on Kuwait Journal<sup>1</sup>. To gain this end we use ANFIS output to assess agility and compare the effects of agile enablers in period of time on capabilities in Iran Khodro manufacture. This recognition helps managers to consider time as leverage factor and focus on this factor to enhance existent agility level and achievement the desired one.*

© 2014 IUST Publication, IJIEPR, Vol. 25, No. 2, All Rights Reserved.

### 1. Introduction

Increasing global competition, especially at the beginning of the 21st century, companies have witnessed significant changes in the market, such as high degree of market volatility, shortened lifecycles, uncertain demand and unreliable supply. Mass markets are continuing to fragment as customers' demands and growing expectations. These developments have caused a major revision of business priorities and strategic vision (Sharifi and Zhang, 1999). On the other

hand, instability and unpredictability of the fast growing technologies has a wrecker effect on the business environment. So the need to respond of volatile environment and apply current technologies has been addressed in recent years by the concept of agility. Companies for surviving and competing with parties in global markets must align with suppliers and customers to streamline operations and cooperate to achieve the level of agility beyond what each one can gain. This integration is termed agile supply chain (ASC) (Yusuf et al., 1999). The idea of creating ASCs has become a logical step for companies, while agility is accepted as a winning strategy for growth and for survival in certain business environments. Agility in supply chain is the ability of supply chain as a whole and its members rapidly align the network and its operation to dynamics and turbulent requirements of the customers (Ismail and Sharif, 2005). Agile

\* Corresponding author: Nazanin Pilevari

Email: [n\\_pilevari@yahoo.com](mailto:n_pilevari@yahoo.com)

Paper first received Nov. 25, 2012, and in accepted form May 29, 2013.

<sup>1</sup> Refer to: "A Novel Framework for Agility Assessment in Supply Chain Considering Enablers and Capabilities", Seyed Hosseini, S.M., Jassbi, J., Pilevari, N., Didekhani, H Kuwait Journal Science and Engineering, 2010.

manufacturing is an expression that is used to represent the ability of producer of goods and services. The changes needed for agile manufacturers to thrive in the face of continuous change can occur in markets, in technologies, in business relationships and in all facets of the business enterprise (DeVor et al. 1997). Maskell (2001) said that three main components of agile production are customer's growth and flourish, compatibility of individuals and information cooperation and change ability. Although supply chain agility is multidimensional concept, in more general sense it can be described as the capability of supply chain functions to provide a strategic advantage by converting unexpected and uncertainties market, potential and actual disruptions into competitive opportunities through assembling requisite assets, knowledge and relationships with speed and surprise (Ngai et al., 2010). The agility is recognized as a winning competitive advantage (Christopher, 2000;

Christopher and Towill, 2001; Dove, 1994; Goldman et al., 1995; Goranson, 1999; Kidd, 1994; Naylor et al., 1999; Oleson, 1998; Sharif and Zhang, 2001; Swafford et al., 2000; Van Hoak et al., 2001; Yusuf et al., 2003; White et al., 2005). Parallel developments in areas of agility and Supply Chain Management (SCM) led to introduction of an agile supply chain (ASC), and it requires wide range of capabilities to respond changing environments (Christopher, 2000). These capabilities include four main elements (Sharp et al., 1999; Christopher, 2000): Responsiveness, Competency, Flexibility and Quickness. According to Gunasekaran (1999), agile manufacturing (AM) is the ability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-defined products and services. Table 1 illustrates some definition with main points of agile supply chain that each author focused on them.

**Tab. 1. Main Points of Definitions of Agile Supply Chain**

Main points of Definitions		
Author	Year	Main Points
Martin Christopher	2000	Enablers of Agile Supply Chain
Denis Towill	2001	Integrated supply chain model to Enable Agile Supply Chain: principles, programs and activities
Edmund Proter	2001	The main parts of the concept of supply chain agility: supply, production, delivery
Y. Yusuf	2003	Determine the capabilities of agile supply chain
Ching Torang Lin	2005	Presenting a Model for evaluating agility in supply chain
Ashis Aghraval	2006	Determining criteria of agility in the supply chain
Swaf ford	2006	Systematic approach to agile supply chain
Daniel Vaznuez	2008	Agility drivers, agile capabilities and its results

As it shows, an agile manufacturer is an organization with a broad vision on the new order of the business world, and with a handful of capabilities and enablers to deal with changes and capture the advantages in global network business. The modern structure of manufacture is forced to transform their pattern of processes and reengineer their processes. The vital element for supply chain is predictable agility by considering resources and customers' need in period of time, however, the theories about agile supply chain not focus on time and its role for progressing agility. This paper set time as the main effective factor on enablers and capabilities to create conceptual models.

## 2. Basic Conceptual Model Construction

Due to the dramatic changes in all aspects, especially in a competitive market, technological innovations, unpredictability within business environment and customer needs, companies must be integrated with suppliers and customers for gain an acceptable agility, which refers to the agile supply chain (ASC). In order to be compatible with changes, we proposed competitive foundations of agility as

follows two main criteria: capability and enablers; each of these attributes focuses on some sub attributes. These factors can leverage agility in supply chain and improve its effectiveness. The basic conceptual model which is developed in two parts; part "A" represents capabilities in three main segments of supply chain: sourcing, manufacturing and delivery (figure 1). Four main attributes (Table 2) and twenty four sub-attributes (Table 3) are the basis of the conceptual model part A. The same procedure has been performed in relation with enablers and Table 5 represents the attributes of enablers which are the basis of the conceptual model part B (figure 2). This model has gained from expert's knowledge and views by using Delphi-Fuzzy method<sup>2</sup> and applying the literature of agile supply chain. The attributes of part A are divided into four main components:

<sup>1</sup>. Refer to "A Novel Framework for Agility Assessment in Supply Chain Considering Enablers and Capabilities" article in Kuwait journal, by Seyed Hosseini, S.M., Jassbi, J., Pilevari, N., Didekhani, H, 2010.

- Responsiveness: which is the ability to identify changes and respond to them quickly, reactively or proactively and also to recover from them.
- Competency: which is ability to efficiency and effectively realize enterprise objectives?

- Flexibility: ability to implement different process and apply different facilities to achieve the same goal.
- Quickness: which is the ability to complete an activity as quickly as possible?

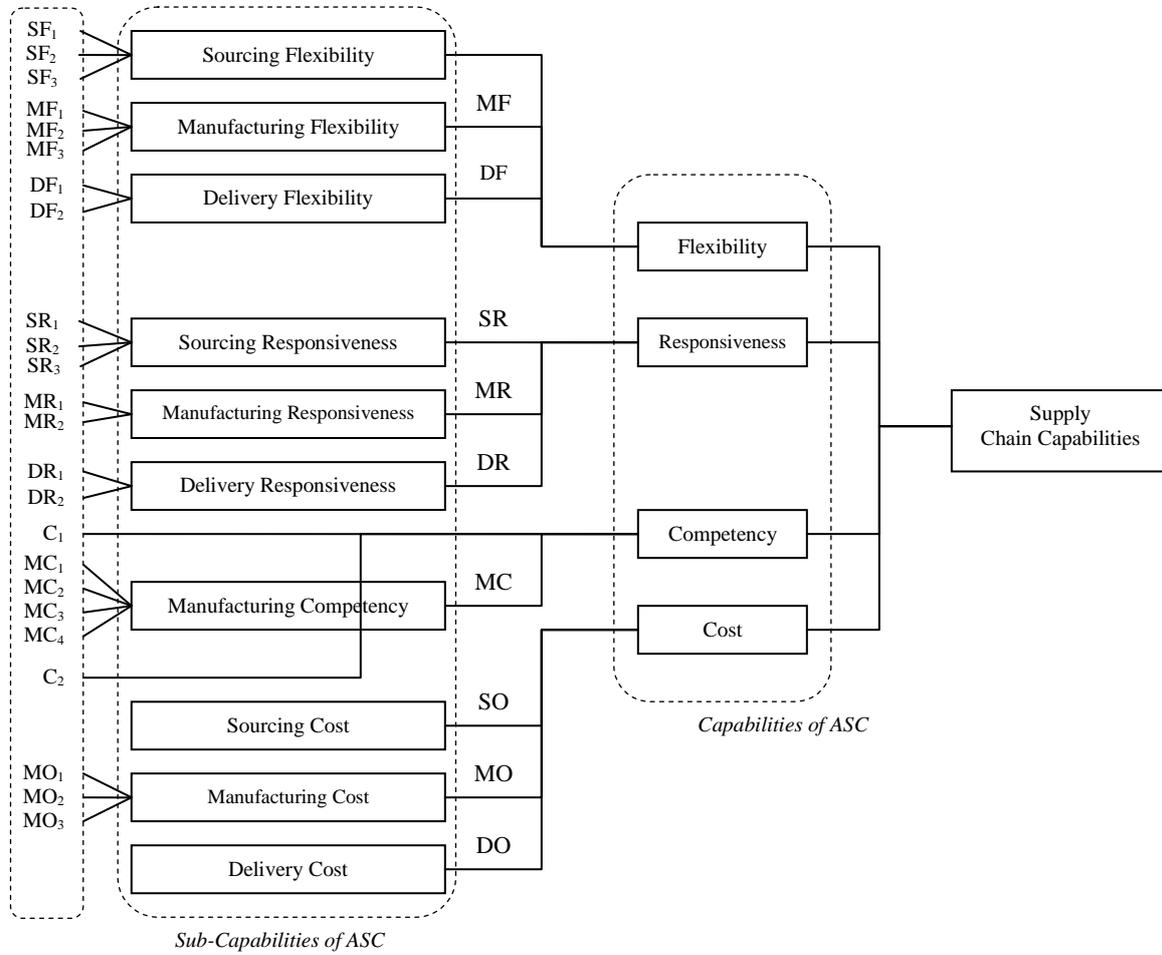


Fig. 1. The conceptual model of capabilities (part A)

Tab. 2. identified Capabilities in the Supply Chain Agility (part A)

Attributes	References
Flexibility	Sharp et al. 1999, Christopher 2000, Swafford et al. 2006, Sharifi and Zhang 1999, Lin et al. 2006
Responsiveness & quickness	Sharifi and Zhang 1999, Goldman et al. 1994, Kidd 1999, Lin et al. 2006, Vickery, Calantone 1999, Handfield & Pannesi 1992, Vickery & Drog 1999, Tersine & Himminbirg 1995
Competency	Lin et al. 2006, Sharif and Zhang 1999
Cost	Swafford et al. 2006, Sharif and Zhang 1999, Van Hoak et al. 2001, Cooper & Enllarm 1993, Goldman et al. 1994, Crocitto & Yusuf 2003

These two parts present as the basic conceptual model of this paper. To approving this model we use Delphi-Fuzzy method by sending questioner to experts several times, applying experts' view for getting the final factors in each group of capabilities and enablers and prepare basic conceptual model. After designed the conceptual model in two domains capabilities and

enablers of supply chain agility, we use Adaptive neuro fuzzy inference system (ANFIS)<sup>3</sup> to assess the agility

3 . For more information about ANFIS, you can read the "A Novel Framework for Agility Assessment in Supply Chain" Considering Enablers and Capabilities" article in Kuwait journal, by Seyed Hosseini, S.M., Jassbi, J., Pilevari, N., Didehkhani, H.2010.

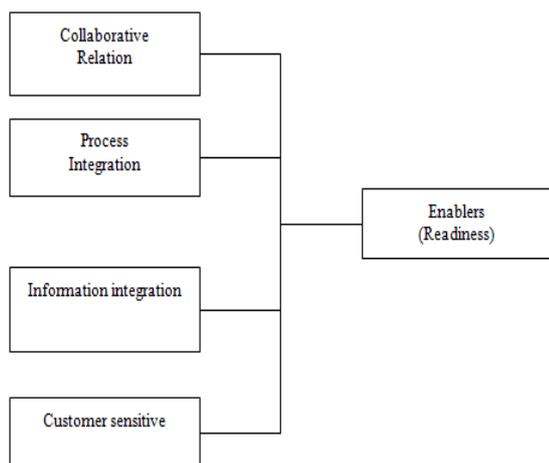
in supply chain of Iran Khodro and to compare how agile enablers can effect on capabilities and in long

time can improve it or lead to regress it.

**Tab. 3. Sub- attributes of the conceptual model (part A)**

Code	Sub-attributes	Reference
SF1	numerous available suppliers	Sharifi and Zhang 1999, Goldman et al. 1994
SF2	flexibility in volume	Sharifi and Zhang 1999, Goldman et al. 1994
SF3	flexibility in variety	Swafford 2006
MF1	flexible manufacturing system	Powar & Sohal 2001
MF2	CAM based manufacturing	Ismail & Sharifi 2005, Towill 2001
MF3	variety and volume of productions	Sharifi and Zhang 1999
DF1	variety of supply schedules for meeting costumers' needs	Swafford 2006
DF2	flexibility in volume of product	Swafford 2006
SR1	Adaptability of deliver time by suppliers	Van Hoak 2001
SR2	suppliers' delivery time	Van Hoak 2001
SR3	supplier relation management	Copanico 1996, Coyle et al.1996
MR1	Time of establishment and changing parts	Sharifi and Zhang 1999
MR2	Responsiveness level to the market changes	Swafford 2006, Goldman et al. 1994
C1	cooperation and internal-external balance	Agrawal & Shankar 2002, Lee et al.1999
MC1	new product introduce	Ismail & Sharifi 2005
MC2	quality of products or services	Swafford 2006, Sharifi & Zhang 1999
MC3	integration	Cristopher & Towill 2001
MC4	time of new product development	Goldman 19994
C2	capabilities of human resources	Willis 1995, Sharifi & Zhang
SO	Sourcing cost	Cooper 1993, Goldman et al.1994
MO1	production cost	Swafford 2006, Goldman et al.1994
MO2	establishment cost	Swafford 2006, Goldman et al.1994
MO3	The cost of changing parts	Swafford 2006, Goldman et al.1994
DO	delivery cost	Van Hoak 2001, Sharifi & Zhang 1999

Figure 2 shows conceptual model of part B and table 4 present the enablers of agile supply chain as part B.



**Fig. 2. The Conceptual model part B (enablers)**

**Tab. 4. identified Enablers in the Supply Chain Agility (part B)**

Attributes	References
Collaborative relation	Christopher, 2000; Christopher & Towill 2001; Agrawal & Shankar 2002
Process integration	Powar & Sohal, A, 2005; Christopher, 2004
Information Integration	Powar & Sohal, A, 2005; Christopher, 2004
Customer Sensitive	Powar & Sohal, A, 2005; Christopher, 2004

ANFIS methodology is one of the appropriate methods for unpredictable condition, when there are not enough accurate documents and decision is just more based on experts' view and their knowledge, also ANFIS can identify the relation between variables. In this research, because of there is no sufficient information and data about agile supply chain, especially about effects of time on enablers and capabilities, we've used ANFIS

Downloaded from ijiepr.iust.ac.ir at 7:28 IRST on Saturday November 25th 2017

method for assessing the amount of these factor on agile supply chain.

Figure 3 shows the architecture of ANFIS (A) for deriving supply chain capabilities and figure 4 presents the architecture of ANFIS for agile enablers.

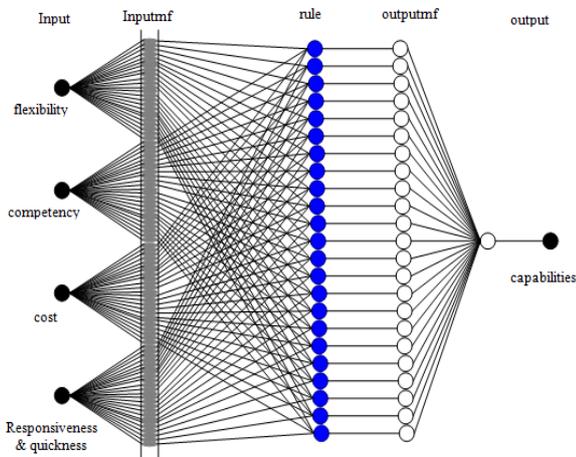


Fig. 3. Architecture of ANFIS (A) for deriving supply chain capabilities

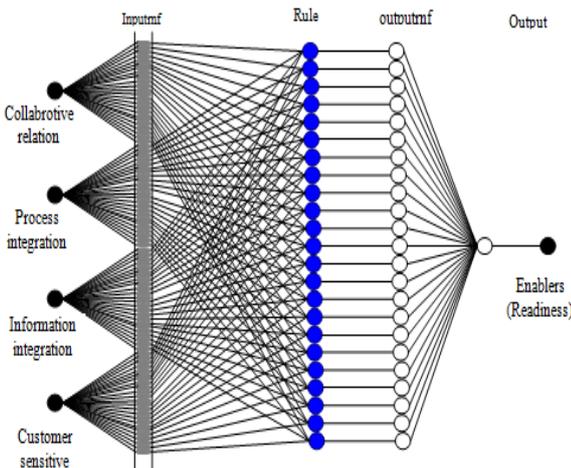


Fig. 4. Architecture of ANFIS (B) for deriving enablers

### 3. Criticis on Basic Coneptual Model

To analyze agility of supply chain in the aspects of capability and enablers, we propose the basic conceptual model. It is apparent that if a supply chain seeks agility, should deal with both capabilities and enablers. In other words, it can be said that agility capabilities are in fact initial agility of supply chain, and the enablers mean readiness to become agile. The important point is that within the organization, the agility enablers need the time to be passed to become agile capabilities.

One of the main critics to this pattern is that it ignores the time. So we try to aggregate the agility capabilities and enablers during the time and then predict the agility of supply chains in different periods of time, in

second proposed pattern. In other words, using the second proposed pattern, we can predict the situation of our given organization in the matrix of agility factors for the future; and studying the dynamic behavior of agility, evaluate the effects of enablers on the agility during the time.

Doing more survey on dynamic systems and consulting the experts, we suggested second proposed pattern using state space equations and Laplace transform functions in two dimensions of capabilities and enablers. This model provides the possibility of aggregating agility capabilities (current status) and agility enablers to observe dynamic behavior of agility during the time.

### 4. Secondary Proposed Conceptual Model to Evaluate Supply Chain

Predictability of agility in supply chain is very critical for manufactures, helps them to improve and achieve advantage. Time has a vital role in ASC, in period of time; enablers effect on capabilities and become new capabilities. Not considering the role of time and its impact on enablers leads to decrease on capabilities and eventually affects agility in over the time. To consider the time dimension in the basic model, redress its deficiency, observing the changes in capabilities and enablers, and their impact on the agility, we can use a mathematical modeling method which is commonly employed in physical and mechanical systems.

A dynamic model is designed to study the behavior of agility over the time. So we used Laplace transform functions to aggregate two dimensions of agility (capabilities and enablers) through the time. To identify the transform function between the two components, capabilities and enablers, asked experts group to answer the following questions:

- How much is the impact of enablers on agility capabilities?
- What is the effect of time constant of enablers on the agility capabilities?
- In the case of lack of investment and lack of agility enablers, how much does it take for agility capabilities to decay? In other words, what is the attenuation rate of agility capabilities?

Their answers use for creating matrix of agility in supply chain, and assess the agility in supply chain of Iran Khodro Company.

### 5. Aggregating Enablers and Capabilities (Matrix of Agility in Supply Chain)

In the view of this research, it seems that two aspects should be considered in analyzing and assessing supply chain: agility capabilities, and agility enablers. These two aspects have mutual interaction, and their balance is the essential condition for agility in the supply chain to be established. The following

figure shows a chart whose horizontal axis represents the agility capabilities in supply chain, and vertical axis represents agility enablers in supply chain. These two dimensions are measured in three terms of low, moderate, and high, and indicate four areas in

coordinate system of axis. This chart is the matrix of agility factors and helps managers and decision makers to analyze the situation and recognize level of agility in supply chain.

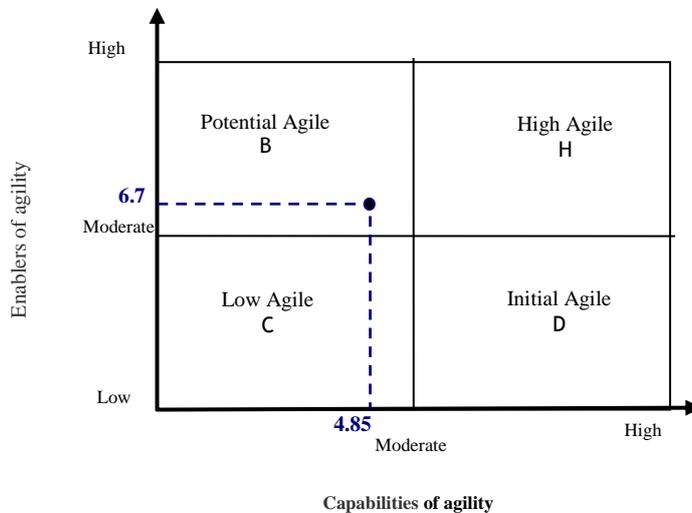


Fig. 5. Placement of Iran Khodro agility in matrix elements of supply chain agility

Here we use the ANFIS outputs for assessing level of capabilities and enablers of agility and by this data we can evaluate Iran Khodro manufacture, is in which part of the matrix, and manager can eliminate their weakness and improve agility. As it's shown the best part in this matrix is in part H, where boat factors are high. Every company tries to achieve this level. Assessing for agility in supply chain in Iran khodro manufacture, as the case study, has been presented in this figure, as it said agility gain from ANFIS method<sup>4</sup>.

Iran Khodro can move up to part H and achieve high agile.

### 6. Implementation Process Secondary Proposed Conceptual Model

As mentioned in section 4, assessing agility of the organization's supply chain, study in two dimensions: capabilities and enablers. Undoubtedly receive agile capabilities need to achieve enablers. In order to provide the secondary model which aggregate enablers and capabilities, proposed a dynamic model by using state space equations and the Laplace transform of functions to predict the agility in supply chain. By using dynamic model can study changes resulting from the interaction of variables and identify their future behavior in different time periods.

#### 6-1. Modeling of Dynamic System

The modeling of dynamic systems is an application can eliminate many of the limitations in decisions making process and can facilitate this process. One approach to study the system dynamic behavior is optimal usage of state space equations and functions of the Laplace transform which proposed model is formed by using this approach. In first step, independent variable  $t$  ( $t$ = time) turns to Laplace variable ( $s$ ) and shift the problem to Laplace space. After solving the problem on Laplace space, answer will be returned back to independent variable ( $t$ ). In this process transition and steady-state components would come together. For transforming the problem from  $t$  to  $s$  and take Laplace space, should use equation 1 in one-way conversion.

Area C: low capabilities, low enablers; in this condition the supply chain is in a static balance state, and is low agile.

Area D: high capabilities, low enablers; in this condition the supply chain is in imbalance state, and is initial agile.

Area B: low capabilities, high enablers; in this condition the supply chain is in imbalance state, and is potential agile, which can be transformed to initial agile during the time.

Area H: high capabilities, high enablers; in this condition the supply chain is in a constant balance state, and is high agile.

As you can see Iran Khodro has potential agile (part B). And it means this manufacture is unacceptable level of agile enablers and it's predictable throughout time

4 . For more information can refer to A Novel Framework for Agility Assessment in Supply Chain Considering Enablers and Capabilities” article in Kuwait journal, by Seyed Hosseini, S.M., Jassbi, J., Pilevari, N., Didekhani, H. publish in Kuwait journal no.

$$L[f(t)] = F(s) = \int_0^{\infty} e^{-st} f(t) dt \tag{1}$$

In this equation the  $f(t)$  is a function of the independent  $t$  variable like time,  $s$  is complex variable,  $L$  is Laplace symbol and  $f(s)$  is Laplace transform  $f(t)$ . To obtain inverse Laplace transform the following equation can be used:

$$L^{-1}[F(s)] = f(t) = \frac{1}{2\pi j} \int_{c-j\infty}^{c+j\infty} F(s)e^{st} dx \quad t > 0 \tag{2}$$

Here  $c$  is the convergence variable or a real constant. We can use Laplace transform tables for transfer every functions to Laplace space. In fact Transfer function is a relationship which indicating the effect a component on other components. For example consider the two components  $i$  and  $j$ , to identify their effectiveness on each other use the dynamic function:

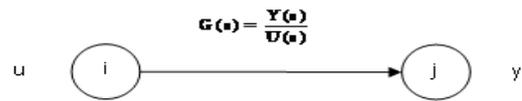


Fig. 6. Relationship between components

In a dynamic system component  $i$  effects on  $j$  based on three factors: Impact, Delay and Frequency. In fact to, if there is a function  $G(s)$ , this clarify the relationship between components  $i$  and  $j$ .

$$G(s) = \frac{K}{\tau S + 1} \tag{3}$$

$$G(s) = \frac{K}{S^2 + 2\xi\Omega S + \Omega^2} \tag{4}$$

In this function  $K$ = Impact,  $T$ = Delay (in stability condition),  $\xi$ = Delay (Damping),  $\Omega$ = Frequency and  $S$  is Laplace variable. As it said the input of Laplace model are the output of ANFIS method.

Tab.5. Effects interaction system data components

Expert	Effective component	impressionable Component	Impact K	Delay $\xi$	Delay-Cap $\theta$
E1	Enablers	capabilities			
E2	Enablers	capabilities			
...	Enablers	capabilities			
En	Enablers	capabilities			

The variables such as impact, delay, delay-cap and frequency of influence can be derived from the experts' views in the form of group decision methods values using verbal variables. If  $\Omega_i=0$ , and  $\xi=ti$ , then the effect of  $i$  on  $j$  would be considered as a first-degree equation (4).

$$G(s) = \frac{K}{S^2 + 2\xi\Omega S + \Omega^2} \tag{4}$$

If we have the  $\Omega_i$  of the influence, and  $\xi=ai$ , then the impact would be considered as a quadratic equation. In a group statement, experts state their views on components of transform function  $G(s)$ . Transform function  $G(s)$  of Laplace transform model is a mathematical relation between the input and output of every component. Since the number of experts is more than one; so with the help of group decision making techniques such as average membership functions, we aggregate their views to find the final values of  $G(s)$  function.

It should be noted that in common approaches to modeling, the historical data are always cited, but for proposed model there is not sufficient historical information about agility capabilities and enablers in supply chain, and the historical data and existing relations in current structures might not be supportive in the future. So that, for presenting model to predict

the supply chain agility at different time intervals, we help of experts' view and their experiences in the field of supply chain agility in the organization.

Also, relying on group decision making methods, receiving the views of experts is sought systematically. Parallel with the critics on the basic pattern based on ignoring the role of time in operationalizing the enablers (agility infrastructures) in supply chains, we designed a dynamic model for studying the agility behavior during the time.

Therefore, in order to aggregate the two dimensions of agility (capabilities and enablers) during the time, we used the Laplace transform function. As it shows, the second conceptual model has two inputs: enablers and capabilities; which values from the ANFIS outputs.

6-2. Secondary Conceptual Model

In this part, we present the final model by focusing on time and its effect. Second suggested model also has three outputs under the name of capability-simout, enablers-simout, and agility-simout, which are showed in the figure8. The first output indicates the behavior of agility capabilities regardless of the enablers, and has a negative slope. The second output indicates the agility enablers, and the third one indicates the behavior of agility in supply chain during the time. Figure 8 shows the stimulated model of agility in supply chain.

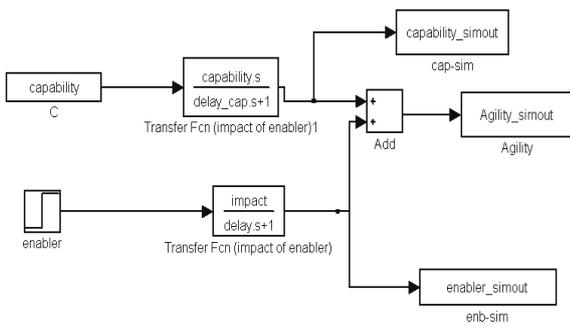


Fig. 8. Second conceptual model of supply chain agility

It should be noted that in  $t=0$ , value of the agility of supply chain is equal with agility capabilities counted in first conceptual model, and during the time this value would be increased by the influence of enablers. So it would be decreased if we ignore agility enablers.

6-3. Validation of the Model

After receiving the extractions from experts about their opinions of agility level of supply chain to the set of inputs values, we divided them into two categories. We used one data set for training ANFIS and the other for validation purpose between ANFIS output and the score which experts have identified. The plot of ANFIS (for capabilities) outputs and testing data has been shown in figure 8. In this plot training data appears at circles with the checking data, appearing as plus, so as it is observed, they conform to each other. In order to validate the accuracy of proposed ANFIS, we compared the model output with experts' knowledge considering capabilities level which has not been used for training ANFIS.

We used mean error and mean magnitude for validating the proposed ANFIS (for capabilities). The mean error between experts' knowledge and the output of model was 0.07 and Mean magnitude of relative error (MMRE) of 0.012 was observed that are acceptable amounts. We have also chosen sign test for significant testing. It is a standard test to test difference between population means for two paired samples which are equal. The hypothesis test is as follows:

$$H_0: \mu_1 = \mu_2 \quad , \quad H_1: \mu_1 \neq \mu_2$$

Test statistic =  $\text{Min}(w^-, w^+)$  , Alpha: Typically set to 0.05

Results: the null hypothesis will be rejected if the test statistic is in critical region. After the hypothesis testing (sign test) PVALUE is calculated .081, considering  $\alpha=0$  and  $PVALUE > \alpha$ . Since  $H_0$  cannot be rejected, there is no significant difference between two paired samples. It means our system behavior doesn't have significant difference with experts' knowledge.

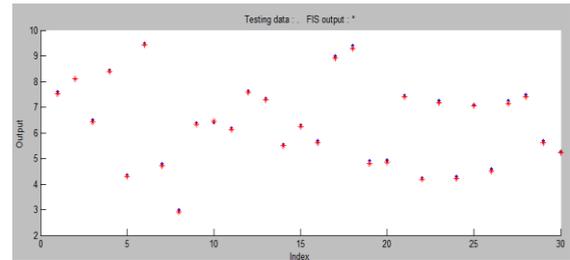


Fig. 7. Comparison of ANFIS (A) outputs and testing data

7. Case Study

The secondary proposed model has been applied to Iran Khodro spare parts and after- sale service co (ISACO). ISACO is an international trading company supplying a wide range of auto spare parts; the company is also distributor for imported brands. Company's domain of activity includes supply automotive parts and services, customer services, dealer and service network, parts sourcing, warranty sales and etc for all automobiles manufactured by Iran Khodro Company, the largest automotive manufacturer in the Middle East.

So it is obvious, how vital and critical an agile supply chain is for this company. The case study to evaluate the agility in ISACO is shown in figure 5, enablers estimate 6.7 (line with circle) and capabilities (line with square) is 4.85. By matching these data and the matrix of agility, find ISACO is in part B (Potential Agile). Now by applying the secondary designed model, we can measure agility over the time. Figure 9 expresses the dynamic behavior of agility, enablers and capabilities in context of time.

As it clear, when  $t=0$  to  $t=5$ , means the first fifth months, the level of the agility is same as the evaluated capabilities (4.85)- because capabilities are the initial agility- and it indicate enablers and agile infrastructure need time for effecting on behavior system. In  $t=10$ , agility has increased from 4.85 to 6.3. Obviously, as time goes on, enablers trace on agility, it means investing on enablers or inattention on this factor, over the time, change the agility, by improving or reducing it.

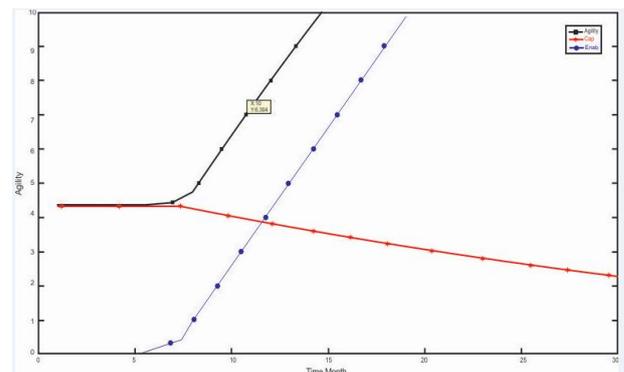


Fig. 9. Dynamic behavior of ISACO agile supply chain

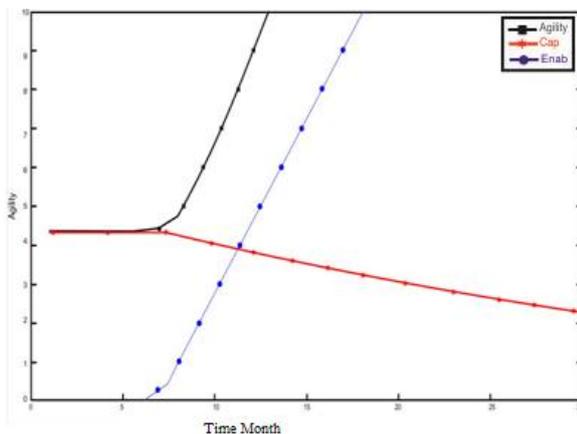
For studying the impacts of time on enablers and then agility, we have implemented the proposed model in a leading car manufacturing company in Iran to prove the applicability of the model and the agility in supply chain of this company is labeled "Potential agile", according to experts' opinions it should be "High agile".

To gain this end, we need the application to predict the level of enablers and agility in any time. So we apply the second suggested model to show how enablers can improve agility in less time and how can predict the level of these factors in different time intervals. This evaluation helps managers to perform gap analysis between an existent agility level (Potential) and the desired one (high). Gap analysis assists to identify obstacles within the organization that could block agility achievement. Table 6 indicates the level of enablers as the readiness in company by using output of ANFIS and it is 6.7. Here by fixing three inputs, model sensitivity measure to change for each of input.

**Tab. 6. Sensitivity analysis of agility enablers**

No	e <sub>1</sub>	e <sub>2</sub>	e <sub>3</sub>	e <sub>4</sub>	Readiness
1	6	7	4	3	6.7
2	7	7	4	3	6.82
3	6	8	4	3	7.42
4	6	7	5	3	7.15
5	6	7	4	4	7.85

First row shows current level of enablers in company and then in each row one of the element increases once (other factor didn't change) and output of ANFIS is in readiness. Dynamic behavior for factor e<sub>4</sub>, illustrate in figure 10.



**Fig. 10. Output of dynamic model for per unit increase in e<sub>4</sub>**

As it's shown, enablers slope increase with the investment in e<sub>4</sub> factor, as a enablers attributes, in less

time intervals can achieve the desired level of agility and it presents rational behavior of the model. Predictability is the main factor we achieved by using this model.

## 8. Conclusion

Since Agile Supply Chain (ASC) is considered as critical competitive advantage in recent years, recognition main factors of supply chain agility and their interactions can be useful and applicable for managers to make more informative and reliable decisions in anticipated changes of volatile markets.

In this paper we use system dynamic method and Laplace function, for redressing the problem on the lack of historical data in the designed model and suggested a method for predicting the agility of supply chain in different time intervals based on two main factors: capabilities and enablers.

In fact interaction between these two factors is considered essential to establish supply chain agility. And showed how enablers can improve capabilities and effect on it in time intervals and of course change agility in supply chain. The dynamic designed model gives managers the opportunity that by considering current enablers and capabilities can predict level of agility in supply chain in future. And help manager and decision maker to identify gap between desirable agility and current situation and investing on enablers more to improve the agility. Because, as it is said, enablers in period of time have a role as lever for capabilities and agility and disregarding it, can decline capabilities and finally agility. So we can say predictability on agile supply chain is the main factor of this paper and also it is an innovative method to measure agility.

The other important finding in this paper is presentation the matrix of agility. With this matrix organizations can identify level of agility in supply chain and planning for promotion.

## References

- [1] Agarwal, A., Shankar, R., Tiwari, M.K., "Modeling Agility of Supply Chain", Int. J.Industrial Marketing Management, Vol. 36, 2007, pp. 443-457.
- [2] Arendt, Wolfgang; Batty, Charles J.K.; Hieber, Matthias; Neubrandner, Frank, "Vector-Valued Laplace Transforms and Cauchy Problems", Birkhäuser Basel, ISBN 3764365498, 2002 .
- [3] Chiu, S., "Fuzzy Model Identification Based on Cluster Estimation", Journal of Intelligent and Fuzzy Systems 2(3): 1994, 267-278
- [4] Christopher, M., Towill, D., "Supply Chain Migration From Lean and Functional to agile and Customized", Supply chain management 5(4): 2000, 206-213.
- [5] Christopher, M., "The Agile Supply Chain: Competing

- in *Volatile Markets*", Industrial Marketing Management 29: 2000, 37-44.
- [6] Close, C.M., Frederick, D.K., "Modeling and Analysis of Dynamic Systems", second edition, John Wiley and Sons, Inc., 1995.
- [7] Dove, R., "Response Ability: the Language Structure and Culture of the Agile Enterprise", John Wiley & Sons, New York, 2001.
- [8] Ganguly, A., Nilchiani, R., Farr, J.V., "Evaluating Agility in Corporate Enterprises", Int. J. Production Economics, Vol. 118, 2009, pp. 410-423.
- [9] Griffin, B., Hesketh, B., "Adaptable Behaviours for Successful Work and Career Adjustment", Australian Journal of Psychology 55 (2), 2003, 65-73.
- [10] Hopp, W.J., Van Oyen, M.P., "Agile Workforce Evaluation: a Framework for Cross-Training and Coordination", IIE Transactions 36 (10), 2004, 919-940.
- [11] Ismail & Sharif, H., "Supply Chain Design for Supply Chain: A Balanced Approach to Building Agile Supply Chain", Proceeding of the International conference on Agility, 2005.
- [12] Pilevari, N., Seyed Hosseini, S.M., Jassbi, J., "Fuzzy Logic Supply Chain Agility Assessment Methodology", IEEM Industrial Engineering, Sinapore. 2008.
- [13] R. Anthony Inman R. Samuel Sale Kenneth W. Green Jr. "Agile Manufacturing: Relation to JIT, Operational Performance and Firm Performance", Journal of Operations Management, Volume 29, Issue 4, May 2011, pp. 343-355
- [14] Seyed Hosseini, S.M., Jassbi, J., Pilevari, N., Didekhani, H., "A Novel Framework for Agility Assessment in Supply Chain Considering Enablers and Capabilities", Kuwait Journal of Science & Engineering, 2010.
- [15] Schwartz, Laurent, "Transformation de Laplace Des Distributions", Comm. Sémin. Math. Univ. Lund [Medd. Lunds Univ. Mat. Sem.] 1952: 1952, 196-206.
- [16] Stratton, R., Warburton, R.D.H., "The Strategic Integration of Agile and Lean Supply", International Journal of production economics 85: 2003, 183-198.
- [17] Swafford, PM., Ghosh, S., Murthy, N., "A Frame Work for Assessing Value Chain Agility", International Journal of operation & production management 26(2): 2006,118-140.
- [18] Vazquez, D., Avella, L., "Agility Drivers, Enablers and Outcomes: Empirical Test of an Integrated Agile Manufacturing Model", International Journal of Operation & Production management 27(12): 2007, 1303-1332.
- [19] Vipul, J., Benyoucef, L., Deshmukh, S.G., "A New Approach for Evaluating Agility in Supply Chain using Fuzzy Associated Rules Mininig", Artificial Intelligence, 2007.
- [20] Vinodh, S., "Improvement of Agility and Sustainability: A Case Study in an Indian Rotary Switches Manufacturing Organization", Journal of Cleaner Production, 2010, pp. 1-6.
- [21] Yi-fen,S., Chyan ,Y., "Why are Enterprise Resources Planning Systems Indispensable to Supply Chain Management?", European Journal of Operational Research, Volume 203, Issue 1, 16 May 2010, pp. 81-94.
- [22] Yusuf. Y., Gunasekaran, A., "Agile Manufacturing: the Drivers' Concepts and Attributes", International Journal of production economics 62-34, 1999.