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RESEARCH PAPER

Agility Factors In Cold Supply Chain Using GRAY-DEMATEL and AHP

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ABSTRACT
Nowadays, the fact that perishable product like dairy products do not reach the customers on time is among the major challenges in the cold chain of perishable products. In this concern, to answer the question of how to make the cold supply chain more agile might lead to the possibility of an increased control over this problem. This study first aimed to identify the factors that affect the agility of the cold supply chain and next applying GRAY-DEMATEL-AHP to rank order them. To collect the required data, the literature of the subject and the opinions of experts and stakeholders who had sufficient experience in the cold chain were obtained. Applying snowball sampling, the identified factors were confirmed after several revisions by Delphi procedure. In addition, in order to take advantage of both GRAY and DEMATEL approaches, the two methods were combined to examine causal relationships among the factors affecting the agility of the cold supply chain. The results indicated that among the sourcing sub-factors, the government decision-making and policies with a weight of 0.212 ranked first and among the distribution sub-factors, loading time and speed of action in distribution, with a weight of 0.188, ranked first. Furthermore, among the sub-factors of production, accurate planning and speed of action in order production, with a weight of 0.342, was at the first rank. The findings of the study might contribute valuable knowledge to the study of the dairy industry cold supply chain agility.

KEYWORDS: *Agility; Cold supply chain; Analytic hierarchy process; GRAY-DEMATEL.*

1. Introduction

Supply chain management is one of the emerging branches of management that is evolving and progressing day by day and is looking for ways to further reduce the production cycle and provide services for the customers while improving the quality of the product and services [8]. Supply chain management is the result of evolution of warehousing management. In the 1960s, experts were able to reduce their inventory by studying the internal relationship between warehousing and transportation and integrating them, the result of which was called distribution management [24]. The chain includes many tasks such as purchasing, cash flow, material transportation, production planning and control, inventory and logistics control, and distribution and delivery [23]. The cold chain is a branch of the supply chain that controls temperature-sensitive and perishable products. Cold chain management is a system that manages various stages of the life cycle of perishable products by effective supervision and planning, and uses appropriate processes and activities to reduce production costs, reduce waste, increase quality, reduce poisoning, increase customer satisfaction, and increase income of producers and other businesses active in the market of perishable products. The emergence of agility has shown significant efforts to address the uncertainty in recently rapidly changing environment [1]. The concept of agility is the implementation of the best solution to remain and succeed in an environment with unpredictable and continuous changes by quick and effective response to changing markets. Agility means the ability to understand the environment and provide appropriate responses to environmental changes

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in the form of time constraints [11]. The supply chain includes companies and business activities needed to design, manufacture, deliver, and use a product or service [13]. Businesses depend on their supply chains to provide what they need to survive and grow [14]. The supply chain years has attracted the attention of many researchers and industrialists in recent. In the supply chain, perishable products have certain characteristics such as short cycle life, special storage conditions, special equipment and facilities for storage, production, distribution, sales, etc. [3]. Therefore, for the management of such products, cold chain management has emerged as one of the new branches in supply chain management [21]. In a turbulent business environment, in order to achieve excellence at all individual, organizational and supply chain levels, achieving the requirements of agility paradigm for manufacturing firms is more important than other emerging concepts in this field [18]. Agility can be increase by good perspective and velocity in supply chains. Firms must have a suitable information of what is happening in their supply chain [7]. Rapid developments in technology, globalization, and competitive markets are environmental features that today's industrial systems are dealing with; previous approaches and solutions have lost their ability to cope with organizational challenges, instability, and changes in a new environment. The most important organizational requirements in the fourth industrial revolution are improving the level of flexibility, agility and effectiveness and using it to meet the growing needs and demands of customers, the requirements for the production and supply of products [19]. Today, supply chain agility is one of the most essential elements in helping organizations, including our country's food industry factories, to be able to continue in this turbulent environment. Various elements can be a facilitator or an obstacle to achieving the above approach. Therefore, identifying the effective elements and their relationships is of special importance to find out the preconditions for the supply chain agility and provide a practical solution for its successful development [31].

Among the perishable products, the authors selected and studied the agility of the cold chain of the dairy industry in Hamedan Pegah Dairy Company using judgmental sampling and snowball method among academic and industrial experts and stakeholders of the cold chain and finally, provided a model for it. Therefore, the aim of this study was to investigate a case study for evaluation of agility and identifying agility in the supply chain. Deng (1982) for first time presented the concepts of GRAY theory from a GRAY set. GRAY theory can remove many of the ambiguities created from wrong decisions. GRAY theory is used to solve problems with uncertainty parameters. The important advantage of GRAY theory is that it helps to procedure satisfactory results with small amount of data [25]. By evaluating the level of agility and studying the literature review, this study seeks to fill the research gap in the field of modelling agility in the cold supply chain by investigating the case of Hamedan Pegah Dairy Company as a well-established company. In other words, this paper seeks to investigate the key factors, identify the correlation between them and provide a model for the factors affecting the agility of the cold supply chain in Hamedan Pegah Dairy Company.

The new contribution of this study is the application of the methodology and its implication in the cold chain of the dairy industry. In this study, a GRAY-DEMATEL method has been used to Evaluation effects of cold chain of perishable products. The methodology used in this study is effective for a wide variety of flexible management and decision making environments. We believe this paper will prepare conditions for future study in create cold chain perishables products. For this purpose, in a real case of a Pegah Dairy company of Hamedan, the effect of the considered indexes on the transportation of perishable products was analysed.

The remainder of this study is presented in next sections. In the section 2, describes literature review of supply chain, agility and cold supply chain. Case study, Data collection, participants and analysis are presented in the section 3. Methodology is presented in sections 4. A real case application is presented in section 5. Finally, conclusion and few suggest for future research are given in section 6.

2. Literature Review

In this section, we will review the recent research in the field of agility in supply chain and cold supply chain. [16] conducted an evaluation of agility in supply chains with a case study of Indian manufacturing organization. [20] stated that the L-A problem for perishable products in the cold chain emphasizes the need for product safety and quality, focusing on specific features such as product useful life, physical demand locations, and product transportation units. Finally, they proposed a decision-making model for allocating cold chain locations to senders and

end users, considering the value deterioration and coordination using the big data approximation. [4], reviewed the coordination of advertising policy and its effect on competition between retailer and manufacture in the supply chain. In this study, evaluated effect of the cooperative promotion efforts in a two-stage supply chain using Game Theory. [15] reviewed and analysed the solutions and technologies available in the field of cold chain traceability and presented the results in the form of a decision support framework (DSF) that included various tables, functions and features in the field of cold chain traceability technology. The results were presented as a decision tree that could be a good solution to solve technical problems and help decision makers to identify, and choose the type of technology and traceable structure of their products in the best possible way while maintaining the safety and quality of products. [2] examined the relationship between information sharing in supply chain and supply chain agility. The case study was a medium-scale manufacturing company in the UAE. They tried to find the main factors for success in the agile supply chain and emphasized on building trust within the supply chain cooperation network to build an agile supply chain. The main factors for success in the agile supply chain were the use of information technology, process integration, proper planning, employee skills development, market sensitivity and responsiveness, new product introduction, flexibility, delivery speed, cost reduction, product quality and customer satisfaction. [6] examined the effect of flexibility in the supply chain and its interaction effect on agility in this chain. The results indicated that agility and flexibility have a direct and positive relationship with each other and increasing one will increase the other. [17] examined the effect of agility in the supply chain. The aim of this paper was to classify agility factors and investigate its relative importance in Indian manufacturing industries. To solve this problem and weight the factor, the Analytic Hierarchy Process (AHP) was used. The results indicated that customer satisfaction and compatibility factors are among the main priorities. The results of sensitivity analysis indicated that the higher the agility of the system gets, the higher the customer satisfaction will be. [9] presented a mathematical model for minimizing energy consumption in the green and agile chain. In their proposed supply chain, discarded materials will be taken from customers and returned to collection canters, recycled from these canters and reused as second-hand materials. The main objective of the nonlinear and three-level mathematical model presented was to minimize costs in the green chain. The findings shown that the proposed model was able to increase the productivity of the system by 98.4%. [22] presented a mathematical model for pricing in the green and agile supply chain. The inverse supply chain included the manufacturer, distributor, customer and collection canters. In this study, three different models were proposed to price products and reduce the costs of the proposed green supply chain. The results indicated that the final price of the product was affected by the collection mode. In Table 1, the relative literature is compared according to goal, method, and specific features focus.

Tab. 1. Relative literature

Source	Year	Goal	Method	Specific feature
Singh et al	2018	Allocation cold chain location	Big data	• Product useful life • Physical demand location • Product transportation units
Asadi and Abolghasemian	2018	Evaluation coordination of advertising policy in supply chain	Game theory	• Local retailer promotion • National producer advertising
Óskarsdóttir and Oddson	2019	Analysed, identified and choose the type of technology in the cold chain	Qualitative research	• Maintaining the safety • Quality of produced
Alzoubi and Yanamandra	2020	Find main factor for success in the agile supply chain	Qualitative research	• Information technology • Process integration

				• Proper planning • Employee skill development • Market sensitivity • Responsiveness
Haq et al	2020	Evaluation the effect of the flexibility in the supply chain	Structural equation modeling	• Flexibility
Patel et al	2020	Examination the effect of the agility	AHP	• Customer satisfaction • Compatibility
Iqbal et al	2020	Minimization energy consumption in the green and agile chain	Mathematical model	• Cost of green chain
Wang et al	2020	Determination a pricing model in the green and agile chain	Mathematical model	• Price product
This paper	2021	Investigate and ranking of the factors of the cold supply chain	GRAY-DEMATEL-AHP	• Loading and speed of action • Company reputation • Control of the temperature • Accurate planning

According to the above mentioned, the importance of agility in the cold supply chain, due to its perishable nature and the time constraints has led the authors to examine and identify important factors affecting the agility of the cold supply chain and then to rank them.

3. Research Method

3.1. Dematel technique

Decision-making trial and evaluation laboratory (DEMATEL) technique was first introduced by Battelle Memorial Institute Geneva research center [26]. Compared with other multi-attribute decision-making (MCDM) methods such as Analytical Hierarchical Process (AHP), DEMATEL technique is a structural modelling method that evaluates inter-dependence relationships and influential effect values between relevant factors with the assists of the cause and effect diagram [25]. The steps of the DEMATEL technique are described below:

- ***Step 1: Compute the initial relation matrix***

The initial relation matrix(A), is the input given by experts on the interrelationships between factors. It shows how each factor influences the other factors in the study. The initial relation matrix is shown as follow Eq.1. The values of each column and row represent the opinion of the experts for the considered index. In the initial matrix, A_{11} is Evaluation of supplier, A_{12} is Temperature and quality of milk, A_{13} is government policy, A_{14} is Liquidity, A_{15} is Remove intermediaries from purchases, A_{16} is Quality of products and equipment and A_{17} is Control the operation of cooling systems.

$$A = \begin{bmatrix} 0 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & 0 \end{bmatrix} \quad (1)$$

- ***Step 2: Normalized initial relation matrix***

The normalized initial relation matrix (N), is calculated using Eq. (2) and (3).

$$X = {}^{1}\!/_{\max \sum_{j=1}^{n} a_{ij}} \quad (2)$$

$$N = X.A \quad (3)$$

Where,X is the normalized value of each factors and A is the normalized of the direct relation-matrix.

- ***Step 3: Total relation matrix*** $(\boldsymbol{Y})$

Total relation matrix (Y) is determined from the normalized matrix (N) by Eq. (4), where I represent the identity matrix.

$$Y = N(I - N)^{-1} \quad (4)$$

$$I_n = \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} \quad (5)$$

- ***Step 4: calculate sum of the rows and columns of the total relation matrix***

$R_{n\times1}$ Represent the sum of the rows, and $R_{1\times n}$ represent the sum of the columns of the total relation matrix.

$$R = \left[\sum_{j-1}^{n} m_{ij}\right] \tag{6}$$

$$C = \left[\sum_{i-1}^{n} m_{ij}\right] \tag{7}$$

- ***Step 5: Causal diagram***

Finally, a causal diagram is built by the $(R_i + C_i)$ and $(R_i - C_i)$ values.

3.2. AHP technique

Analytic hierarchy process (AHP) is a well-known multi-criteria decision making (MCDM) method in industries [27]. AHP is based on pairwise comparisons of alternative and factors. In this paper, the weights of the alternatives and then their rank are determined using AHP method. The steps of the AHP method are described below:

- ***Step 1: pairwise comparison matrix (D)***

According to the experts opinions building a pairwise comparison matrix, for alternatives.

$$D_{n\times m} = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \ddots & \vdots \\ d_{n1} & \cdots & d_{nm} \end{bmatrix} \tag{8}$$

- ***Step 2: normalized pairwise comparison matrix(N)***

It is calculated by Eq. (9).

$$N = \begin{bmatrix} d'_{11} & \cdots & d'_{1n} \\ \vdots & \ddots & \vdots \\ d'_{n1} & \cdots & d'_{nn} \end{bmatrix}, \quad d'_{ij} = {1}\Big/{\sum_{i=1}^{j} d_{ij}} \tag{9}$$

- ***Step 3: computation of the factor weights.***

$$V = \begin{bmatrix} v_1 \\ \vdots \\ v_n \end{bmatrix}, \quad V_j = {\sum_{i=1}^{n} d'_{ji}}\Big/{n} \tag{10}$$

$$V' = NV = \begin{bmatrix} v'_1 \\ \vdots \\ v'_2 \end{bmatrix} \tag{11}$$

where N, is the matrix order and V', is the factor weight matrix.

3.3. GRAT theory

A GRAY number like $\otimes X = [\underline{X}, \overline{X}]$ can be represented by an interval with an upper bound $(\overline{X})$ and a lower bound $(\underline{X})$, but the statistical distribution of X is unknown for us. GRAY numbers can easily convert into crisp numbers using modified- CFCS method. According to CFCS generation crisp scores with GRAY numbers, let $\otimes X_{ij}^{k}$ represents the GRAY number of an expert k who evaluates the effect of factor i on factor j. We can reach the crisp values by following equations (12-15).

- ***Step1: Normalization***

$$\underline{\otimes} X_{ij}^{k} = (\underline{\otimes} X_{ij}^{k} - \min \underline{\otimes} X_{ij}^{k})\Delta_{min}^{max}, \tag{12}$$

$$\overline{\otimes} X_{ij}^{k} = (\overline{\otimes} X_{ij}^{k} - \min \overline{\otimes} X_{ij}^{k})\,\Delta_{min}^{max}, \tag{13}$$

where, $\Delta_{min}^{max} = \max \overline{\otimes} X_{ij}^{k} - \min \underline{\otimes} X_{ij}^{k}$.

- ***Step 2: Calculation of total normalized value***

$$Y_{ij}^{k} = \frac{\underline{\otimes} X_{ij}^{k}\left(1 - \underline{\otimes} X_{ij}^{k}\right) + (\overline{\otimes} X_{ij}^{k} * \underline{\otimes} X_{ij}^{k})}{1 - \underline{\otimes} X_{ij}^{k} + \overline{\otimes} X_{ij}^{k}} \tag{14}$$

- ***Step 3: Computational of final crisp scores***

$$Z_{ij}^{k} = \min \otimes X_{ij}^{k} + Y_{ij}^{k}\Delta_{min}^{max} \tag{15}$$

4. Results

4.1. Case study: hamedan pegah dairy company

Iran Dairy Industries Company called Pegah is the biggest dairy factory in the Middle East. Pegah can produce 1.5 million tons of milk per year. At present, 30% of domestic Iranian market is supplied by Pegah. Hamedan Pegah is one of the group of companies that is located in Hamedan. Hamedan Pegah dairy is one of the most important industrial units in Hamedan province since 1956. Today, it has 24 distribution factory and more than 1000 personnel.

4.2. Data collection

In this paper, to data gathering, the literature of the subject and the opinions of experts and

stakeholders who have sufficient experience in the cold chain have been used and the identified factors have been confirmed after several revisions by the Delphi method and snowball sampling. In the first round, a list of 65 factors affecting the agility of the dairy industry's cold supply chain was identified by literature and interview, then was provided to the group members to give their opinions about them and give a score of 1 to 7 to each factor. In addition, they were interviewed to add their opinions in the form of suggestions for correcting the factors and even add a new factor if they have one in mind. At this stage, the board members removed some of the 65 available factors. In the second stage, the revised questionnaire was redistributed among experts to give a score to the importance of the mentioned factors from 1 to 7 (1 = very insignificant, 2 = insignificant, 3 = relatively insignificant, 4 = moderate, 5 = relatively important, 6 = Important, 7 = very important) and if they had new opinions, they could mention them. At this stage, the experts did not have a new opinion, but they were asked to examine the factors with a more detailed and meticulous look and identify the factors that were closely related to each other and could be integrated. The experts stated that all of the above factors are important in this chain, but emphasized on selection of the most effective factors of cold chain agility in the dairy industry. In table 2 main factors, sub foetors and final point in Delphi has been shown. It should be noted that all steps of Delphi technique have been performed by the author. All data in this paper is recorded from July 2018 to June 2019.

Tab. 2. Main factors and sub- factors used

Main factor	Sub-factors	Final point in Delphi
Sourcing(C1)	Use of standards to select and evaluate suppliers (C11)	5.68
	Monitoring the temperature and quality of raw milk inlet (C12)	5.78
	Government Decision-Making and Policies (C13)	5.63
	Liquidity (C14)	5.86
	Remove intermediaries from purchases (C15)	5.94
	Quality products and equipment suppliers (C16)	5.58
	Cooling systems performance control (C17)	6.62
Production(C2)	Staff Status (C21)	5.79
	Application of modern production methods (22)	6.62
	Accurate planning and speed of action in order production (C23)	5.89
	Satisfaction in production and welfare services (C24)	5.79
	Reduce production costs by using specialized personnel (C25)	6
	Monitoring and quality control of products throughout the production process (C26)	6.37
Distribution(C3)	Flexibility in refrigerated vehicles and distribution staff (C31)	5.84
	Tracking and routing using IT capabilities (C32)	5.79
	Loading time and speed of distribution (C33)	5.87
	Capillary distribution and customer access to the product (C34)	6.11
	Impact of corporate reputation (C35)	5.89
	Deep and ongoing interaction with customers (C36)	5.68
	Suitable place for distribution (C37)	5.89

4.3. Participants

Potential experts and stakeholders in the field of the cold supply chain were selected. Data analysis on respondents' gender distribution is as follows: The male participants is 81.25% and the female participants is 18.75%. The participants aged 20 to 30 years, 30 to 40 years, 40 to 50 years, and over 50 years is 9.37, 50, 40.63 and 0 percent, respectively. Work experience of less than 5 years, 5 to 10 years, 10 to 15 years, 15 to 20 years, and more than 20 years is 6.25, 21.87, 21.87, 31.25 and 18.75 percent, respectively. Finally, the participants in terms of education for bachelor's, master's, and doctoral degrees is 31.25, 53.12 and 15.63 percent, respectively.

4.4. Analysis

Achieving consensus and decision-making on stopping or continuing Delphi loops requires a criterion, one of which is the Kendall correlation

coefficient. The Kendall correlation coefficient, shown by the symbol$w$, is a non-parametric test and is employed to determine the degree of correlation between opinions. The Kendall coefficient varies between 0 and 1. If the Kendall coefficient is zero, it means that there is complete non-consensus, and if it is one, it means that there is complete consensus. Kendall correlation coefficient is calculated from the following equation:

$$w = \frac{\mathrm{s}}{\frac{1}{12}k^2(N^2-N)}, \quad (16)$$

where, S is equal to the sum of the squared deviations of R_{Js} from the mean R_{Js},

$$S = \sum[R_{j-}\frac{\sum R_{j-}}{N}]^2, \quad (17)$$

where, R_j is the sum of the ranks related to a factor, K is the number of sets of ranks. The value of this scale is equal to one, when there is complete correlation and zero when there is lack of correlation. The Kendall correlation coefficient for the respondents in this study is 93%. Given that the number of board members is more than 10, so this Kendall coefficient is completely significant. The factor identification algorithm is shown below:

Start:

Step 1: run first round of the Delphi method. In this step, we determining the important factors of agility, and go to the step 2.

Step 2: calculate average importance of expert opinion and go to step 3.

Step 3: re-send questionnaires to the experts. In this step, we can identify another important factor if there is another important factor we must add it to the factors set and back to the step 2 otherwise, go to the step 4.

Step 4: run second round of the Delphi method. In this step, experts can change their opinion. If experts change their opinion, back to the step 2 otherwise, go to the step 5.

Step 5: calculate the Kendall correlation coefficients. If the Kendall coefficient is zero, back to the step 1, and if it is one stop.

Stop

After the final consensus was reached and the factors were identified, in the next step, the GRAY-DEMATEL technique was used to investigate the effectiveness and affectability of the factors and the analytical hierarchy method (AHP) was used to determine their importance and weight. In the present study, 11 experts were selected to answer DEMATEL and AHP questionnaire, which these 11 people were selected from the Delphi participation board, with the feature that the respondent team at this stage had a higher level of knowledge and expertise in the field. They included 1 university expert who had worked in the field of cold supply chain and 10 industrial experts, each of whom was a senior manager in various departments related to cold supply chain with at least 10 years of work experience. They had education, expertise and experience in this field and also had enough information about other fields. The proposed framework for our research is shown in Fig. 1.

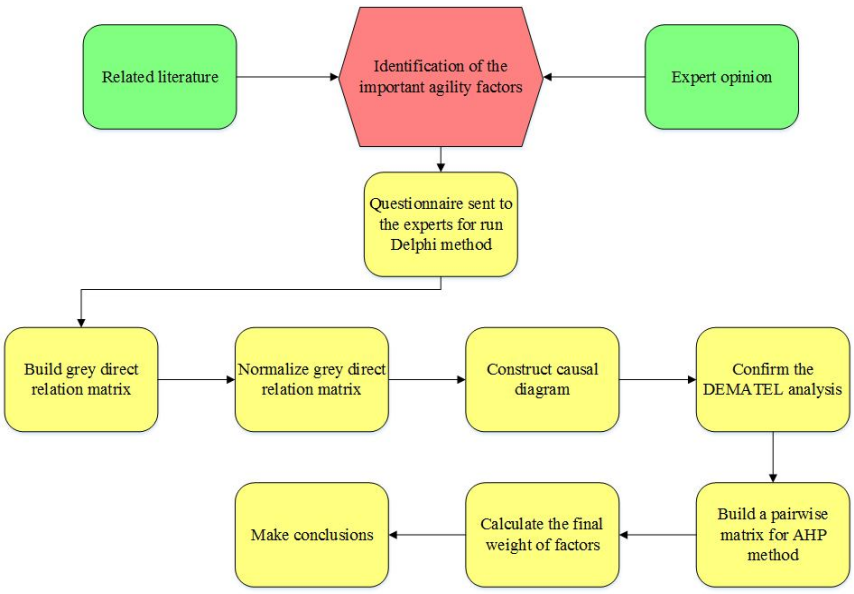

Fig. 1. Proposed research framework

4.5. Proposed GRAY-DEMATEL technique

In this paper we report implementation of Gray Dematel just in sourcing department as a sample.

Step1: Compute the initial relation matrix.

Suppose that the number of considered index of cold supply chain be n and the participant response chosen to be i. Each participant k is respond of index i over index j according to Table 3. Therefore, initial relation matrix were established based on the influence rating from participant response.

Tab. 3. Predetermined effects intervals in the GRAY-DEMATEL method (Bhatia et al., 2018)

Name	GRAY value
No effect	[0,0]
Low effect	[0,0.25]
Medium effect	[0.25,0.5]
High effect	[0.5,0.75]
Very high effect	[0.75,1]

Step2: Forming the direct relation matrix: in this step, we first form the GRAY initial relation matrix based on the spectrum of Table 4. This matrix is derived from the arithmetic mean of 11 experts' opinions.

Step3: Calculating the normal direct relation matrix: to normalize, first we calculate the sum of the elements of each row, then from the sum of the rows, we select the maximum value, which in this study is equal to 6,562, and each element of determined direct relation matrix is divided by this value. The normal matrix is given in Table 5.

Step4: Causal diagram: the threshold value must be calculated to determine the network relation map (NRM). In this method, minor relations can be ignored and a network of significant relations will be drawn. Only the relationships which their values in the matrix T that is $T = N \times (I - N)^{-1}$, where N is normalized matrix and I is identity matrix that shown in Table 6 are greater than the threshold value will be displayed in NRM that indicated in Table 7. To calculate the value of the relation threshold, it is sufficient to calculate the mean values of the matrix T. Once the threshold value has been determined, all values of the matrix T that are smaller than the threshold will get zero, meaning that their causal relationship is not considered. In this study, the threshold value was 0.627. In table 6, significant relationship pattern are shown.

Tab. 4. GRAY direct relation matrix

	C11	C12	C13	C14	C15	C16	C17
C11	[0,0]	[0.477,0.727]	[0.182,0.364]	[0.477,0.727]	[0.341,0.568]	[0.591,0841]	[0.455,0.682]
C12	[0.409,0.614]	[0,0]	[0.136,0.295]	[0.455,0.682]	[0.386,0.614]	[0.614,0.864]	[0.545,0.795]
C13	[0.455,0.705]	[0.295,0.477]	[0,0]	[0.5,0.727]	[0.409,0.636]	[0.364,0.591]	[0.273,0.477]
C14	[0.568,0.818]	[0.477,0.705]	[0.386,0.545]	[0,0]	[0.614,0.864]	[0.591,0.818]	[0.433,0.659]
C15	[0.295,0.477]	[0.295,0.523]	[0.205,0.386]	[0.545,0.795]	[0,0]	[0.432,0.682]	[0.364,0.591]
C16	[0.364,0.614]	[0.409,0.659]	[0.045,0.159]	[0.364,0.545]	[0.295,0.477]	[0,0]	[0.432,0.682]
C17	[0.341,0.523]	[0.523,0.773]	[0.136,0.25]	[0.295,0.477]	[0.227,0.409]	[0.545,0.773]	[0,0]

Tab. 5. Normalized matrix (N)

	C11	C12	C13	C14	C15	C16	C17
C11	0.000	0.170	0.083	0.169	0.123	0.191	0.153
C12	0.132	0.000	0.064	0.153	0.134	0.197	0.185
C13	0.161	0.100	0.000	0.164	0.139	0.128	0.102
C14	0.189	0.160	0.125	0.000	0.197	0.181	0.148
C15	0.099	0.116	0.089	0.185	0.000	0.153	0.132
C16	0.139	0.153	0.039	0.115	0.098	0.000	0.157
C17	0.109	0.182	0.050	0.100	0.083	0.171	0.000

Tab. 6. Matrix T

	C11	C12	C13	C14	C15	C16	C17
C11	0.57	0.77	0.39	0.74	0.64	0.86	0.75
C12	0.67	0.61	0.37	0.71	0.63	0.85	0.76
C13	0.67	0.66	0.30	0.66	0.61	0.76	0.66
C14	0.79	0.83	0.46	0.67	0.76	0.93	0.81
C15	0.60	0.66	0.37	0.69	0.48	0.76	0.67
C16	0.58	0.64	0.29	0.58	0.52	0.56	0.64
C17	0.55	0.65	0.60	0.57	0.50	0.71	0.50

Tab. 7. Significant relationship pattern

	C11	C12	C13	C14	C15	C16	C17
C11	×	0.770	×	0.742	0.644	0.865	0.742
C12	0.669	×	×	0.710	0.633	0.846	0.759
C13	0.665	0.661	×	0.693	×	0.756	0.659
C14	0.792	0.827	×	0.665	0.758	0.930	0.815
C15	×	0.658	×	×	×	0.765	0.667
C16	×	0.365	×	×	×	×	0.636
C17	×	0.654	×	×	×	0.708	×

According to the relationship pattern in Table 6, causal diagram can be drawn that shown in Table 8.

Tab. 8. The causal relationship pattern of identified factors

	D	R	D+R	D-R
C11	4.742	4.431	9.173	0.311
C12	4.590	4.812	9.904	0.222
C13	4.434	2.474	6.817	1.869
C14	5.251	4.646	9.897	0.606
C15	4.216	4.144	8.360	0.072
C16	3.379	5.426	9.223	1.630
C17	3.783	4.788	8.571	1.006

In Table 8, the sum of the elements of each row (D) indicates the extent to which a factor affects the other factors of the system. Accordingly, the liquidity criterion (C14) is most effective. The sum of the elements of column (R) for each factor indicates the affectability of that factor from other factors of the system. Accordingly, the criterion of quality of supplier products and equipment (C16) has a very high affectability. Horizontal vector (D + R) is the amount of effectiveness and affectability of the desired factor in the system. In other words, the higher the D + R value is, the more interactive it is with other system factors. Accordingly, the liquidity criterion (C14) has the highest interaction with other factor. The vertical vector (D-R) indicates the power of effectiveness of each factor. In general, if D-R is positive, the variable is considered a causal variable, and if it is negative, it is considered to be the effect. In this model, the factor of using the standard to select and evaluate suppliers (C11), government policies and decision-making (C13), liquidity (C14), elimination of intermediaries from purchases (C15) are the causal variables and monitoring the temperature and the quality of the raw milk (C12), the quality of supplier products and equipment (C16) and the performance control of the cooling systems (C17) are the effect. In Fig. 2. Shown the Cartesian coordinate system of DEMATEL output for factors.

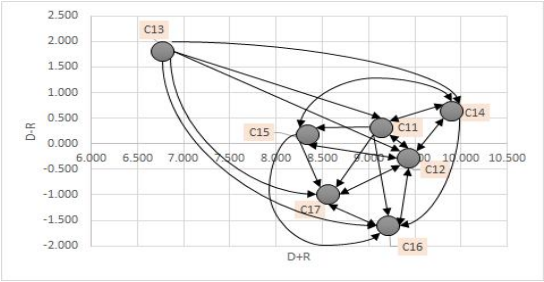

Fig. 2. Causal diagram of DEMATEL output for factors

4.6. AHP method

In the previous steps, the research factors were studied using the GRAY-DEMATEL method in terms of effectiveness and affectability. In this step, analytic hierarchy process (AHP) is used to define their importance and weight. The following steps are the results of pairwise comparisons and weights results.

Step 1: Pairwise comparison of main factor: in this section, pairwise comparisons of 3 main factors are given in Table 9. The ***inconsistency*** rate of this pairwise comparison is 0.08, and since it is less than 0.1, it indicates acceptable consistency.

Tab. 9. Pairwise comparisons of the main factor

	C1	C2	C3
C1	-	4.078	3.846
C2		-	2.298
C3			-

Step 2: Pairwise comparison of sourcing sub-factor: the sourcing criterion has 7 sub-factor, the pairwise comparisons of which are given in Table 10. The ***inconsistency*** rate of this pairwise comparison is 0.04.

Tab. 10. Pairwise comparisons of sourcing sub-factor

	C11	C12	C13	C14	C15	C16	C17
C11	-	1.566	0.501	0.383	0.919	0.852	2.109
C12		-	0.756	0.792	0.609	0.926	2.297
C13			-	2.591	1.290	0.609	3.252
C14				-	1.574	1.122	2.633
C15					-	0.762	1.461
C16						-	2.240
C17							-

We enter the pairwise comparisons in the Expert choice software, where the weights of the factors are calculated and shown in Fig. 3.

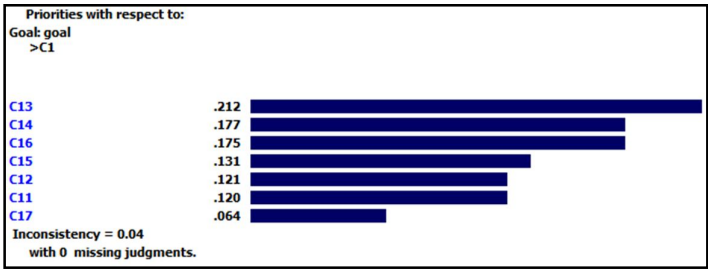

Fig. 3. Weights of sourcing sub-factor

According to Fig. 3. Among the sourcing sub-factor, government decision-making and policies with a weight of 0.212 has gained the first rank. Liquidity weighing 0.177 and the quality of supplier products and equipment weighing 0.175 ranked second and third, respectively.

Step 3: Pairwise comparisons of production sub-factor: the production criterion has 6 sub-factor. The ***inconsistency*** rate of this pairwise comparison is 0.04. We enter the pairwise comparisons in the Expert choice software, where the weights of the factor are calculated and shown in Fig. 4.

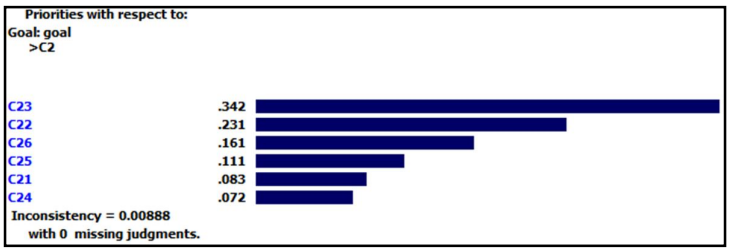

Fig. 4. Weights of production sub-factor

According to Fig. 4. Among the production sub-factor, proper planning and speed of action in order production with a weight of 0.342 has gained the first rank. The use of new production methods with a weight of 0.231 and the monitoring and quality control of products throughout the production process with a weight of 0.161 have obtained the second and third ranks, respectively. According to Table 11, among the sub-factor of distribution, loading time and speed of action in distribution with a weight of 0.188 has gained the first rank. The impact of the company's reputation and fame with a weight of 0.155 and the control of temperature fluctuations in transportation vehicles with a weight of 0.129 have earned second and third rank, respectively.

Tab. 11. Weights and ranks of distribution sub-factor

Name of the factor	Code	Weight	Rank
Loading time and speed of action in distribution	C33	0.188	1
The impact of the company's reputation and fame	C35	0.155	2
Control of temperature fluctuations in transportation vehicles	C39	0.129	3
Deep and continuous interaction and communication with customers	C36	0.120	4
Use of IT capabilities in traceability and routing	C32	0.112	5
Intensive distribution and customer access to the product	C34	0.092	6
Quality of the vehicle and cooling equipment of transportation vehicle	C38	0.084	7
Flexibility in cold vehicles and distribution staff	C31	0.074	8
Appropriate distribution location	C37	0.047	9

Step 4: The final weight of the sub-factor: for obtaining the final weight of the sub-factor, the weight of each dimension is multiplied by the weight of the criterion and then multiplied by the relative weight of the sub-factor, which is done by Expert Choice software and shown in Fig. 5. Accordingly, among the 22 sub-factor, government decision-making and policies (C13) has gained the first rank. After that, liquidity (C14) and the quality of supplier products and equipment (C16) ranked second and third, respectively.

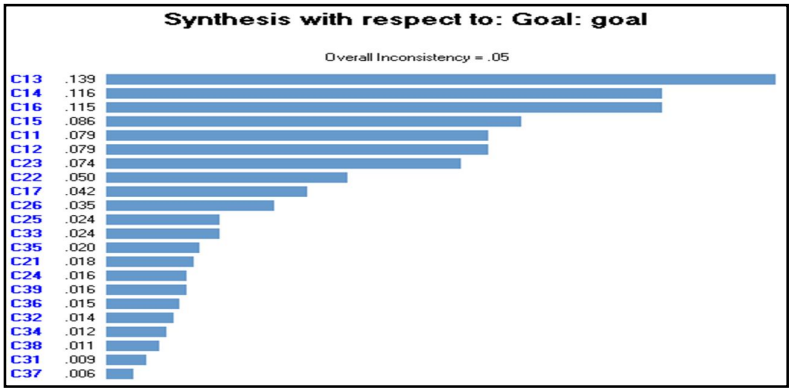

Fig. 5. Weights and final ranks of sub-factor

5. Conclusion

The purpose of this study is to modelling the factors affecting the agility of the cold supply chain, with a case study of Hamedan Pegah Dairy Company. This study was conducted specifically focusing on the factors affecting the agility of the cold chain of dairy products. The research was descriptive-survey and applied in terms of objective. In order to answer the research questions, after collecting information using the interviews and the researcher-made questionnaire, Delphi method was used to identify and rank the collected factors. So, using snowball and judgmental sampling method, 32 people were selected among the statistical population consisting of managers, university professors, experts in the field of research. The initial 65 factors collected through library research and interviews were finally adjusted to 22 factors in the form of three main stages of the supply chain over three stages of using the Delphi method. After the final consensus was achieved in the third stage by the Kendall coefficient of 93%, the next step was to examine the effectiveness and affectability of the factors using the GRAY-DEMATEL technique and to determine their importance and weight by analytical hierarchy process (AHP). Factors affecting cold chain agility in this study were divided into three categories: sourcing, production and distribution. The sub-sets of the sourcing stage included these items: Use of standards to select and evaluate suppliers, monitoring the temperature and quality of raw milk, government decision-making and policies, liquidity, elimination of intermediaries from purchases to reduce the total cost of products, quality of supplier products and equipment, control of the performance of cooling systems. The sub-sets of the production stage included: employee status (the importance of computer training, removing the limitations of teaching methods, the creation of a motivating environment for learning, job rotation), the use of new production methods (increasing product durability using the new production methods such as ESL process), proper planning and speed of action in order production, satisfaction in

production and welfare services that create product quality and increase production efficiency, reducing production costs by using expert staff to reduce prime cost and break-even price, monitoring and quality control of product throughout the production process (supervision of a food industry expert throughout the production process and quality control of manufactured products and their packaging). Also, in the production stage, the employee status has been the most effective factor, and the criterion of reducing production costs by using expert staff to reduce prime cost and break-even price has had the highest affectability and also this criterion has had the most interaction with other factors. At this stage, the factors that were considered as the cause were: employee status (the importance of computer training, removing the limitations of teaching methods, the creation of a motivating environment for learning, job rotation), the use of new production methods (increasing product durability using the new production methods such as ESL process), proper planning and speed of action in order production, flexibility in vehicles and staff, IT capabilities in traceability and identifying loading time from promise to action, the impact of the company's reputation and fame in production and welfare services that create the quality of products increase production efficiency; and the factors that were considered as the effect included reducing production costs by using expert staff, and monitoring and quality control of product throughout the production process (supervision of a food industry expert throughout the production process and quality control of manufactured products and their packaging). Results shown that this paper adds valuable knowledge to the study of the dairy industry cold supply chain. In this study, the GRAY-DEMATEL method was used to evaluate the effects of the supply chain of perishable products. The method used in this study is effective for a wide range of flexible management and decision making environments and provides valuable results. One of the factors that caused the time limitation for the researcher was choosing the suitable factory for the research. At first, the researcher wanted to cooperate with a factory other than Hamedan Pegah Dairy Company, but after a few months of follow-up, the cooperation with the mentioned factory did not continue. Another limitation of this research was the use of Delphi method and consequently the use of the opinions of various experts, and because the experts were too busy, it was sometimes difficult to access them or they responded too late. Finally, for future research, the authors suggest expanding this method to use other methods such as TOPSIS, ELECTRE, and compare their results.

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