Numerical and Experimental To Evaluate Of Supply Chain Performance Measurement Dairy Industries via Using Fuzzy Analytical Hierarchical Process and Fuzzy Logic

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Abstract

With the modern orientation of companies which concentrates mainly on customer, globalizations, and high competition position, this caused the supply chain members must be under high pressure to manage and control their effectiveness. So measuring of supply chain performance in such circumstances can be considered as a crucial effect and it is implemented in this paper. This research aims to estimate supply chain performance measurement based on Fuzzy Analytical Hierarchical Process. In real application, the performance of organization estimated based on different factors and these factors vary in impact on performance depending upon policies and strategies of organization. The importance of each factor was identified by applying Fuzzy Analytical Hierarchical Process technique. Two phases fuzzy logic rule were applied, the first phase i.e. fuzzy inference system was used to identify performance indicator of each factor by using its value and importance. The second phase was started by using second fuzzy inference system to identify supply chain performance measurement by integration of all factor indicators which obtained from first inference rule. The developed approach provides an effective tool for evaluation of supply chain performance measurement and real case study was presented in dairy industries.

Key words: Supply chain performance measurement, Fuzzy extended performance measurement, Fuzzy analytical hierarchical process.

1. Introduction

The establishing of performance measurement system (PMS) considered first step toward assessment of performance of organizations. Tangen (2003) stated the (PMS) characteristics which are[1]

- PMS must be across organization's strategy and must have a balance attitude to metrics, which considered vital for the organizations.
- PMS should be concentrated on the short and long-term results.
- PMS should have cohesion through organizations strategy and must be explained in usefully manner.

Today, the business have a fewer boundaries around because of globalization, information technology, and outsourcing[2]. These new factors of business environment have present a motive to improve the perspective of managerial functions. The new perspective of managerial function required appropriate metrics and performance measurements to arise supply chain efficiency[3].

The performance measurement of supply chain enables the managers to have succeed managing of the supply chain efficiently [4]. Effective supply chain considered important element to the organization to maintain sustainable in competitive advantage; to achieve that, (SCPM) is necessary[5].

Waggoner et al. (1999) says that the performance measurement of supply chain provides a suitable path to identify the area which require more awareness and also to help in improving the connection level among supply chain members[6].

In (2002) Simatupang and Sridharan mentioned that a continues development of supply chain members, end customers satisfaction, and outer stakeholders could be easily achieved by applying an efficient performance measurement approach[7].

2. Literature review

Adel Benz (2011) was presented Fuzzy performance measurement which considers important approach to calculate supply chain performance measurement (SCPM). The application of proposed approach which is used to evaluate performance revealed that the effects of quantitative and qualitative factors on (SCPM) can be integrated into single indicator. The proposed approach uses fuzzy set theory with Analytical Hierarchy Process (AHP) in order to identify the performance[8]. The researcher developed its approach by applying Fuzzy Analytical Hierarchical Process (FAHP) but for each department separately and then integrates them into union evaluation, while in the proposed approach the evaluation made based on weighting the main variables which identified and weighted by expert depending on organization policy and make this evaluation in monthly biases.

David C. Hall & Can Saygin (2012) developed a framework uses simulation to examine the impact of information sharing rate, on-time delivery, and total cost supply chain. The performance indicators of capacity rarity، reliability of resource and information sharing system which is related to resource reliability information, demand of customer, and stock level. These factors were chosen and then tested by simulation approach. They concluded the importance of information sharing which is lead to decrease cost. But, it is difficult to apply in low trust or dynamic supply chains. Also the study revealed that the interaction between capacity tightness, reliability, and the modes of information sharing depending on the level of operational parameters[9].

Charkha and Jaju (2014) suggested a supply chain performance measurement (SCPM) for textile industry. They focus on three main performance metrics: human resources, production operation scheduling, and inventory. After selection these criteria for estimation of the performance, the questionnaire were designed and distributed to identify the relative importance of these three metrics from various levels of an organization. The Comparison the three performance metrics on each specific indicator will be done, and then relative weight was computed. All this steps done by applying analytical hierarchical process (AHP) which considered commonly used tool to solve this type of problems[10]. But these researchers took the variables in equally level while in presented research the variables were took different weights depending on organization policy, while in current research the using of (FAHP) helped to overcome the problem of ambiguity and how to deals with expert opinions, also they employed fuzzy logic to create indicator for each selected variable and then integrate these indicators also by using new fuzzy logic.

Developed approach to examine the supply chain performance measurement, modern system of measurement must examine the performance of individual member of supply chain and entire supply chain system was studied by R. Tarasewicz (2016). Questionnaire was applied and method of Computer Assisted Telephone Interviewing (CITI) used to solve the problem. The target people of the questionnaire was 79 executive director out of the top 500 managers of ranked companies, the researcher show that 97% of the responses indicated the critical importance of performance indicators in the supply chain[11].

3. Proposed approach Description

The proposed approach in this research which is used to identify (SCPM). Different parameters were selected to evaluate (SCPM), these parameters are total cost (TC), inventory turnover (INT), raw material consumption (RM), and safety stock level (SS). The main steps of the proposed approach are explained as below:-

1. Applying (FAHP) technique to identify the importance (weight) of each one of this predefined parameter.
2. Employment of first fuzzy inference system (FIS1) to identify indicators for each one of the four parameters. The obtained indicators are cost indicator (**CI**), inventory turnover indicator (**INI**), raw material indicator (**RMI**), and safety stock level indicator (**SSI**).
3. Integration of these indicators in to second fuzzy inference system (FIS2) to identify (SCPM).
4. The researcher selected (FAHP) to identify the (SCPM) by weighting the variables, instead of different approaches such as Taguchi method where this method (Taguchi method) cannot used to asses the variables depending on expert knowledge because it deals with specific values of parameter (level of parameter) which is don’t appear in this case.**

The architecture of proposed approach is presented in figure (1).

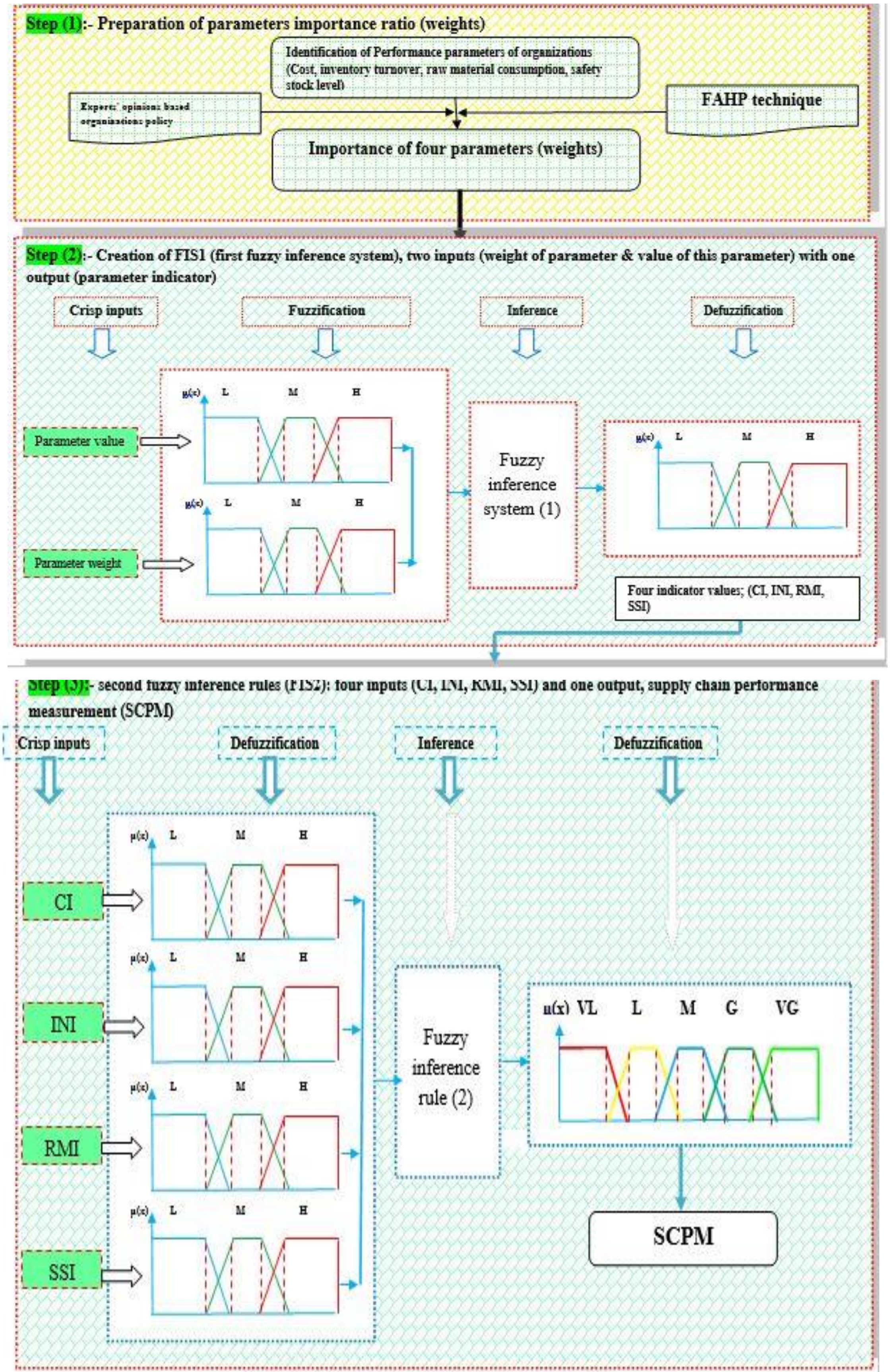

Figure (1) Architecture of proposed approach

3.2 Case study

A real case study was applied to prove the success of the proposed approach. The implementation of proposed approach was presented in dairy industries as shown in steps below:

Step (1):

Fuzzy analytical hierarchical process (FAHP) was presented to identify the importance of each parameter based on organization policy; the steps are summarized as follow;

a) Preparation of the Table (1) which connect linguistic expression with triangular fuzzy number. Figure (2) presents linguistic expression of parameters importance;

Table (1): Triangular fuzzy numbers scale.

No.	Definition	Fuzzy triangular scale
1	More important-absolute (MI.AB)	(7/2,4,9/2)
3	More important-very strong (MI.VS)	(5/2,3,7/2)
5	More important-fairly strong (MI.FS)	(3/2,2,5/2)
7	More important-week (MI.W)	(2/3,1,3/2)
9	Equal important	(1,1,1)

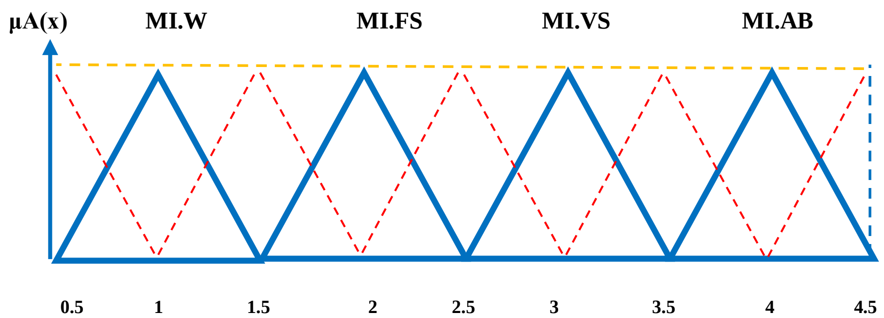

Figure (2): Linguistic expression of parameters

b) Create the comparison matrix, which represents expert judgment of preference of each parameter against other.

c) Checking of expert opinion consistency (CR) to ensure the validity of his opinion.

CR=CI/RI

CI (consistency index) = (λ_{max} n) / (n-1).

RI (random index) value taken from specific Table (standard table) depending on number of comparison parameters, Table (2) shows the values of this index.

Table (2): Random index (RI) values corresponding to number of parameters

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

d. Aggregation of experts' opinions in order to integrate their knowledge and obtain the importance of each parameter. The results of integrated experts' opinions are showing in Table (3).

Table (3): Combined results of experts opinions

Aggregation of experts knowledge												
	cost			product inv.			raw material inv.			covered SS		
cost	1.00	1.000	1.000	1.108	1.414	1.750	1.583	2.060	2.603	0.905	1.000	1.107
Inventory turnover	0.572	0.707	0.906	1.000	1.000	1.000	0.906	1.189	1.540	0.651	0.841	1.108
raw material inv.	0.387	0.412	0.633	0.649	0.841	1.107	1.000	1.000	1.000	0.420	0.540	0.720
covered SS	0.905	1.000	1.107	0.902	1.189	1.538	1.392	1.861	2.390	1.000	1.000	1.000

e. using of synthetic extent in order to estimate the priorities of parameters by following the steps below[12]:-

- ✓ Summation of each row value and then combined the values, equation (1) represents this procedure

Summation value $=(\sum_{i=1}^{n} l_i), \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i$ ………….. (1). By applying this equation for firs parameter (cost), $(summation\ l = (1 + 1.108 + 1.583 + 0.905) =$ **4.596**.),(m =**5.474**), (u =**6.46**). The table (4) represents the result of applied same procedures for all parameters values.

Table (4): Summation values of parameters

No.	l	m	u
cost	4.596	5.474	6.460
Inventory turnover	3.129	3.737	4.554
Raw material	2.457	2.793	3.460
covered SS	4.199	5.050	6.035
SUM.	14.381	17.05	20.5

- ✓ Identification of inverse value for each one of summation values, equation (2) represents this procedure

Inverse value = $\left({}^{1}/_{\sum_{i=1}^{n} u_i}, {}^{1}/_{\sum_{i=1}^{n} m_i}, {}^{1}/_{\sum_{i=1}^{n} l_i} \right)$………. (2). Applying equation (2) gives us inverse values as ($u^{-1} = \left(\frac{1}{20.5}\right) = 0.048, m^{-1} = 0.055, l^{-1} = 0.069$)

- ✓ Identify synthetic extent by multiplying summation values with inverse values, for example in first parameter (cost); $l = 4.596 * 0.048) = 0.22$. Repeat same procedure to obtain Table (5)

Table (5): Synthetic extent of parameters

l	m	u
0.048	**0.055**	**0.069**
0.22	**0.32**	**0.45**
0.15	**0.22**	**0.32**
0.12	**0.16**	**0.24**
0.2	**0.3**	**0.42**

- ✓ Applying comparison formula, equation (3),

$$comparison = \begin{cases} 1\ if\ m2 \geq m1 \\ 0\ if\ l1 \geq u2 \\ \frac{l1-u2}{m2-u2-m1+l1}\ otherwise \end{cases} \quad \text{……………………………………. (3)}$$

- ✓ For parameter (1), (0.22,0.32,0.45), make comparisons with the second, third, and fourth rows to identify the value at each time

U1 against U2;

(0.22,0.32,0.45)≥ $(0.15,0.22,0.32)$ =1

(0.22,0.32,0.45)≥ $(0.12,0.16,0.24)$ =1

(0.22,0.32,0.45)≥ $(0.20,0.30,0.42)$ =1

- ✓ Repeat same procedure for all parameters to get all comparison value.
- ✓ Select minimum value of each parameter.
- ✓ Normalization of this value to obtain the importance of each parameter

After implementation of algorithm above the result is obtain as shown in Table (6) which represent the importance of parameters

Table (6): importance of four parameters

Cost	Inventory turnover	Raw material	Safety stock
0.396	**0.198**	**0.044**	**0.36**

Step (2); first fuzzy inference system (FIS1) to identify parameter indicator

In this step, all data required are feed to the model. These data represent the quantity level of four parameters, which are cost level, inventory turnover times, raw material consumed, and safety stock level. For example, in January cost value is (573,802,204 IQD), inventory turnover is (3.04), raw material consumed (882.17), and safety stock level is (0.329),

In this phase, the indicator of parameter for each one is determined by using the fuzzy inference system (**FIS1**) which is consists of two input variables and one output. The input variables are the importance of the parameter and its value, while the output variable is parameter indicator. Refereeing to the Table (6) which represents the importance of parameters (input no. 1) with the values of parameters obtained from organization data base (input no. 2) which shown in Table (7). By applying (FIS1) for example to the January month, the (CI) is (0.355), (INVI is 0.183), (RMI is 0.183), and (SSI is 0.697). repeating same procedurs for Table(7), the results were obtained as shown in Table (8) below:

Table (4-29): Data of four parameters before applied the proposed approach

Month	Total cost	**Inventory (money)**	**Sales (money)**	Inventory turnover	Raw material	Safety stock
January	573,802,204	**189303120**	**575093548**	3.03	882.17	0.329
February	466,335,690	184514916	529724632	2.87	811	0.3517
March	479,744,476	418846808	550472064	1.3	757	0.72
April	471,651,087	357698514	509065582	1.21	668.1	0.58
May	477,038,472	331029664	477302794	1.44	658.2	0.617
June	499,235,960	359452662	560417966	1.56	689.8	0.77
July	332,741,132	409534782	380831778	0.93	485.7	1
August	440,428,546	340908336	422382434	1.24	561.7	0.76
September	297,456,296	209027610	312879760	1.5	414	0.77
October	359,029,114	411734818	336244320	0.82	332.7	0.53
November	366,864,344	148883058	338533578	2.27	429.19	0.4
December	392,311,618	197087958	400015744	2.03	530	0.59

Table (8): The parameters indicator of current organization

Month	Cost indicator	Inventory indicator	Raw material indicator	Safety stock indicator
January	0.355	0.183	0.183	0.697
February	0.424	0.183	0.183	0.68
March	0.483	0.183	0.19	0.417
April	0.407	0.183	0.202	0.446
May	0.39	0.183	0.202	0.446
June	0.311	0.183	0.21	0.453
July	0.808	0.183	0.44	0.194
August	0.501	0.183	0.303	0.386
September	0.8	0.183	0.5	0.446
October	0.795	0.183	0.5	0.194
November	0.761	0.183	0.5	0.602
December	0.659	0.183	0.363	0.562

Step (3): Second Fuzzy Inference system (FIS2) to identify SCPM

The third phase of the proposed approach is to identify performance of supply chain by applying Second Fuzzy Inference system (FIS2). Indicators values of all parameters are provided to the (FIS2) which represent input variables values while the output is (SCPM), referring to Table (8) and enter these values to the system, the performance measurement of supply chain is calculated. For example in January month (CI=O.355), (INVI=0.183), (RMI=0.183, (SSI=0.697) after applying (FIS2) the (SCPM =9%). Table (9) shows the results of (SCPM) after applying (FIS2).

Table (9) SCPM before applied of proposed approach

Month	January	February	March	April	May	June	July	August	September	October	November	December
SCPM	9%	10%	10%	11%	11%	12%	44%	44%	50%	50%	55%	41.8%

After applying the proposed approach, the (SCPM) was shown in Table (9) which clearly appears that the organization is suffering in the first six month due to low level of (INVI) indicator. While for the next six month the (SCPM) was increasing due to the development occurred in this variable.

4. Conclusions

The proposed approach provide with evaluation for performance of organization in monthly biases and this gives an important impression of the work in organization, which is needed by organization to diagnose the weaknesses and strength points to correct their performance. Also the using of (FAHP) technique enhances the process of evaluation (SCPM) because in most researches these variables were taken with equally impact.

The calculation of supply chain performance measurement periodically (monthly) in order to show the true picture of the performance of organization because the adoption of this method on an annual basis may lead to the blurring of many indicators of the performance of the organization due to overlapping factors affecting during year, which makes the annual performance picture very vague and imprecise.

The introduce of (FAHP) technique considered a critical element in evaluating the performance of the organization because it takes into consideration the importance of each one of the four variables based on the organization policy.

The application of (FAHP) technique to identify the importance of each factor will ensure the alignment of performance measurements with supply chain policy. Table (10) shows the abbreviation which is used in the research

Table (10); the abbreviation used in the research.

Symbol	*Definition*
AHP	Analytical Hierarchy Process
CAT	Computer Assisted Telephone Interviewing
FIS1	first fuzzy inference system
FAHP	fuzzy analytical hierarchical process
INTI	inventory turnover indicator
PMS	performance measurement system
RMI	raw material consumption indicator
SSI	safety stock level indicator
FIS2	second fuzzy inference system
SCPM	supply chain performance measurement
CI	total cost indicator

CONFLICT OF INTERESTS.

- There are no conflicts of interest.

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دراسة رقمية وتجريبية لتقييم مؤشرات اداء سلسلة تجهيز صناعات الالبان بطريقة عملية التحليل الهرمي المضبب

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الخلاصة: -

مع التوجه الحديث للشركات التي تركز بشكل رئيسي على العملاء، العولمة، والمنافسة العالية، تسبب هذا في أن يكون أعضاء سلسلة التوريد تحت ضغط عال لإدارة ومراقبة فعاليتها. لذلك يمكن اعتبار قياس أداء سلسلة التوريد في مثل هذه الظروف تأثيرًا حاسمًا ويتم تنفيذه في هذا البحث. يهدف هذا البحث إلى تقدير قياس أداء سلسلة التوريد على أساس العملية الهرمية التحليلية الضبابية. في التطبيق الفعلي، يتم تقدير أداء المنظمة بناءً على عوامل مختلفة وتختلف هذه العوامل في التأثير على الأداء وفقًا لسياسات واستراتيجيات المنظمة. تم تحديد أهمية كل عامل من خلال تطبيق تقنية العملية الهرمية التحليلية الضبابية. تم تطبيق مرحلتين من قواعد المنطق الضبابي. تم استخدام المرحلة الأولى والتي تمثل نظام الاستدلال الغامض الاول لتحديد مؤشر الأداء لكل عامل باستخدام قيمته وأهميته. بينما بدأت المرحلة الثانية باستخدام نظام الاستدلال الغامض الثاني لتحديد قياس أداء سلسلة التوريد من خلال دمج جميع مؤشرات العوامل التي تم الحصول عليها من. يوفر النهج المتطور أداة فعالة لتقييم قياس أداء سلسلة التوريد وقدمت دراسة حالة حقيقية في صناعات الألبان.

الكلمات الدالة: - مؤشرات اداء سلسلة التوريد، مؤشرات الاداء الضبابية الموسعة، التحليل الهرمي الضبابي.