بسم الله الرحمن الرحیم

بهینه‌سازی استوار
و کاربردهای آن در مدیریت زنجیره تامین

روشی برای کاهش تعداد سناریوهای تصادفی

مدرس: میر سامان پیشوایی

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دی‌ماه ۱۳۹۲ – ویرایش اول

دانشگاه علم و صنعت ایران

بر اساس

Pishvaee M.S., Fathi M., Jolai F. (2008).

A fuzzy clustering-based method for scenario analysis in strategic planning: The case of an Asian pharmaceutical company.

South African Journal of Business Management, 39: 15-25.

سنــاریو

- یکی از راه های برخورد با عدم‌قطعیت استفاده از روش برنامه ریزی تصادفی مبتنی بر سناریو است.
- هدف از ایجاد سناریو کشف محتمل ترین یا ممکن ترین حالات برای پارامترها و جمع بندی آن در قالب تصویرهای (سناریوهای) محتمل‌تر یا ممکن‌تر می‌باشد.
- سپس این امکان برای تصمیم‌گیران وجود دارد که تصمیمات را با توجه به سناریوها طراحی و تدوین کنند.

طراحی سناریو (ادامه)

- سناریو یک توصیف (منطقی) از شرایط آینده (داخلی و محیطی) است.
- باید دقت کرد که سناریو تنها مجموعه ای فرضیات در مورد وقایع آینده نیست بلکه این فرضیات باید شفاف، مهم، سازگار و مربوط باشند.
- سناریو هم می‌تواند به کمک عبارات کیفی یا هم به صورت اعداد کمی ارائه شود.
- تیم های طراحی سناریو معمولاً با توجه به ماهیت سناریو تیم های چند تخصصی باید باشند.

چگونه سناریو (کمی) بسازیم

- ابتدا پارامترهای دارای عدم قطعیت را شناسایی کنید.
- مقادیر محتمل برای هر یک از پارامترها را با توجه به رفتار تاریخی و یا برآورد خبرگان استخراج کنید.
- تجمیع هر یک حالات بوجود آمده برای پارامترهای دارای عدم قطعیت یک سناریو را بوجود خواهد آورد.
- باید دقت کرد که سناریوهای بوجود آمده یک فهرست حداکثری از سناریوهای ممکن می‌باشد.

مثال برای تحلیل استراتژیک محیط

Main areas	Key Factors	Future trends of key factors		
Political	1	1	2	3
	2	1	2	
Economical	1	1	2	
	2	1	2	
Cultural & Social	1	1	2	3
Technologic al	1	1	2	
	2	1	2	3
Demographica l	1	1	2	
Possible Scenarios		Scenario No.1 (P1.1, P2.1, E1.1, E2.1, C1.1, T1.1, T2.2, D1.1,)	Scenario No.2 (P1.3, P2.1, E1.1, E2.1, C1.1, T1.1, T2.2, D1.1,)	...

مثال موسسه تحقیقات دارویی مورد مطالعه در مقاله

<table>
<tr><th rowspan="2">Scenario No.</th><th colspan="14">Forecasted quantities</th></tr>
<tr><th>P1.1</th><th>P1.2</th><th>P2.1</th><th>P2.2</th><th>E1.1</th><th>E1.2</th><th>E2.1</th><th>E2.2</th><th>E2.3</th><th>E3.1</th><th>E3.2</th><th>C1.1</th><th>C1.2</th><th>D1.1</th></tr>
<tr><td>1</td><td colspan="2">P1.1</td><td colspan="2">P2.1</td><td colspan="2">E1.1</td><td colspan="3">E2.1</td><td colspan="2">E3.1</td><td colspan="2">C1.1</td><td>D1.1</td></tr>
<tr><td>2</td><td colspan="2">P1.2</td><td colspan="2">P2.1</td><td colspan="2">E1.1</td><td colspan="3">E2.1</td><td colspan="2">E3.1</td><td colspan="2">C1.1</td><td>D1.1</td></tr>
<tr><td>.</td><td colspan="2">.</td><td colspan="2">.</td><td colspan="2">.</td><td colspan="3">.</td><td colspan="2">.</td><td colspan="2">.</td><td>.</td></tr>
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<tr><td>46</td><td colspan="2">P1.2</td><td colspan="2">P2.1</td><td colspan="2">E1.1</td><td colspan="3">E2.3</td><td colspan="2">E3.2</td><td colspan="2">C1.2</td><td>D1.1</td></tr>
<tr><td>47</td><td colspan="2">P1.1</td><td colspan="2">P2.1</td><td colspan="2">E1.2</td><td colspan="3">E2.3</td><td colspan="2">E3.2</td><td colspan="2">C1.2</td><td>D1.1</td></tr>
<tr><td>48</td><td colspan="2">P1.2</td><td colspan="2">P2.1</td><td colspan="2">E1.2</td><td colspan="3">E2.3</td><td colspan="2">E3.2</td><td colspan="2">C1.2</td><td>D1.1</td></tr>
<tr><td>.</td><td colspan="2">.</td><td colspan="2">.</td><td colspan="2">.</td><td colspan="3">.</td><td colspan="2">.</td><td colspan="2">.</td><td>.</td></tr>
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<tr><td>95</td><td colspan="2">P1.1</td><td colspan="2">P2.2</td><td colspan="2">E1.2</td><td colspan="3">E2.3</td><td colspan="2">E3.2</td><td colspan="2">C1.2</td><td>D1.1</td></tr>
<tr><td>96</td><td colspan="2">P1.2</td><td colspan="2">P2.2</td><td colspan="2">E1.2</td><td colspan="3">E2.3</td><td colspan="2">E3.2</td><td colspan="2">C1.2</td><td>D1.1</td></tr>
</table>

چالش مهم

- تعداد بالای سناریوها تصمیم‌گیری را با مشکلات جدی مواجه می‌کند.
- یکی از مشکلات مهم افزایش پیچیدگی مسئله به ازاء افزایش تعداد سناریوها می‌باشد.
- این مشکل به خصوص در مسائل برنامه‌ریزی تصادفی مبتنی بر سناریو و مدل‌های استوار مبتنی بر آن جدی می‌باشد.

متدولوژی کاهش سناریو

Step 1 Defining key factors and describing their possible future trends in the opinion of experts.

Step 2 Generating all possible scenarios from a combination of factors' future trends.

Step 3 Calculating pair wise compatibility indexes and eliminating incompatible scenarios.

Step 4 Defining main scenarios with Fuzzy C-means clustering (FCM) method and ranking them by calculating the degree of possibility for each final scenario.

Step 5 Project the cluster centres for expressing and interpreting the main scenarios in linguistic terms.

دو قانون برای کاهش سناریو

سناریو باید شفاف، مهم، سازگار و مربوط باشند.

- To determine the degree of possibility of a scenario that shows its importance, a **fuzzy compatibility index (*FCI*)** between each pair of forecasted future trends is defined.
- The concept of **triangular fuzzy number (TFN)** is used for this purpose. As shown in Figure 4, five linguistic variables as TFNs between 1 to 5 ($FCI_{(i,\,j)}$)
- For eliminating the incompatible scenarios two rules were used:

1. If one or more than one of *FCIs* between each pair of forecasted quantities/trends (*FCI (i, j)*) in a scenario is "very low" the related scenario will be eliminated.

2. If the average of *FCIs* in a scenario is less than "Medium" (or fuzzy number), the related scenario will be eliminated.

بررسی سازگاری دو به دو مقادیر

	P1.1	P1.2	P2.1	P2.2	E1.1	E1.2	E2.1	E2.2	E2.3	E3.1	E3.2	C1.1	C1.2	D1.1
P1.1			$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
P1.2			$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{4}$	$\tilde{3}$	$\tilde{2}$	$\tilde{1}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
P2.1					$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
P2.2					$\tilde{3}$	$\tilde{4}$	$\tilde{4}$	$\tilde{3}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$
E1.1							$\tilde{3}$	$\tilde{3}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{2}$	$\tilde{3}$
E1.2							$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$	$\tilde{4}$	$\tilde{3}$
E2.1										$\tilde{2}$	$\tilde{4}$	$\tilde{4}$	$\tilde{1}$	$\tilde{2}$
E2.2										$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
E2.3										$\tilde{4}$	$\tilde{2}$	$\tilde{2}$	$\tilde{4}$	$\tilde{4}$
E3.1												$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
E3.2												$\tilde{2}$	$\tilde{4}$	$\tilde{4}$
C1.1														$\tilde{2}$
C1.2														$\tilde{4}$
D1.1														

اعمال دو قانون بر سناریوهای اولیه

Scenario No.	Scenario Value	Elimination Rule 1	Elimination Rule 2	Scenario No.	Scenario Value	Elimination Rule 1	Elimination Rule 2
1	2,904	not rejected	rejected	**49**	2,952	not rejected	rejected
2	2,904	rejected	rejected	**50**	2,952	rejected	rejected
3	2,952	not rejected	rejected	**51**	3	not rejected	not rejected
4	3,142	rejected	not rejected	**52**	3,047	rejected	not rejected
5	2,85	rejected	rejected	**53**	3	rejected	not rejected
6	3,14	not rejected	not rejected	**54**	3,285	not rejected	not rejected
7	2,904	rejected	rejected	**55**	3,095	rejected	not rejected
8	3,238	not rejected	not rejected	**56**	3,428	not rejected	not rejected
9	2,809	rejected	rejected	**57**	2,857	rejected	rejected
10	2,809	rejected	rejected	**58**	2,857	rejected	rejected
11	2,904	rejected	rejected	**59**	3	rejected	not rejected
12	2,952	rejected	rejected	**60**	3,047	rejected	not rejected
13	2,857	rejected	rejected	**61**	3	rejected	not rejected
14	3,142	rejected	not rejected	**62**	3,285	rejected	not rejected
15	3	rejected	not rejected	**63**	3,190	rejected	not rejected
16	3,333	rejected	not rejected	**64**	3,523	rejected	not rejected
17	3	not rejected	not rejected	**65**	3	not rejected	not rejected
18	2,904	rejected	rejected	**66**	2,904	rejected	rejected
19	3	not rejected	not rejected	**67**	3,047	not rejected	not rejected
20	2,952	rejected	rejected	**68**	3	rejected	not rejected
21	2,857	rejected	rejected	**69**	2,952	rejected	rejected
22	3,047	not rejected	not rejected	**70**	3,142	not rejected	not rejected
23	2,904	rejected	rejected	**71**	3,047	rejected	not rejected
24	3,142	not rejected	not rejected	**72**	3,285	not rejected	not rejected
25	3,047	not rejected	not rejected	**73**	3,047	not rejected	not rejected
26	2,952	rejected	rejected	**74**	2,952	rejected	rejected
27	3,142	not rejected	not rejected	**75**	3,190	not rejected	not rejected
28	3,095	rejected	not rejected	**76**	3,142	rejected	not rejected
29	3	rejected	not rejected	**77**	3,095	rejected	not rejected
30	3,190	not rejected	not rejected	**78**	3,285	not rejected	not rejected
31	3,142	rejected	not rejected	**79**	3,285	rejected	not rejected
32	3,523	not rejected	not rejected	**80**	3,523	not rejected	not rejected
33	3,047	not rejected	not rejected	**81**	3	not rejected	not rejected
34	2,857	rejected	rejected	**82**	2,809	rejected	rejected
35	3,095	not rejected	not rejected	**83**	3,142	not rejected	not rejected
36	2,9045	rejected	rejected	**84**	3	rejected	not rejected
37	2,809	rejected	rejected	**85**	2,857	rejected	rejected
38	2,904	not rejected	rejected	**86**	2,952	not rejected	rejected
39	2,952	rejected	rejected	**87**	3,047	rejected	not rejected
40	3,095	not rejected	not rejected	**88**	3,190	not rejected	not rejected
41	3,190	not rejected	not rejected	**89**	3,142	not rejected	not rejected
42	3	rejected	not rejected	**90**	2,952	rejected	rejected
43	3,380	not rejected	not rejected	**91**	3,380	not rejected	not rejected
44	3,238	rejected	not rejected	**92**	3,238	rejected	not rejected
45	3,047	rejected	not rejected	**93**	3,095	rejected	not rejected
46	3,142	not rejected	not rejected	**94**	3,190	not rejected	not rejected
47	3,285	rejected	not rejected	**95**	3,380	rejected	not rejected
48	3,428	not rejected	not rejected	**96**	3,523	not rejected	not rejected

Clustering vs. Classification

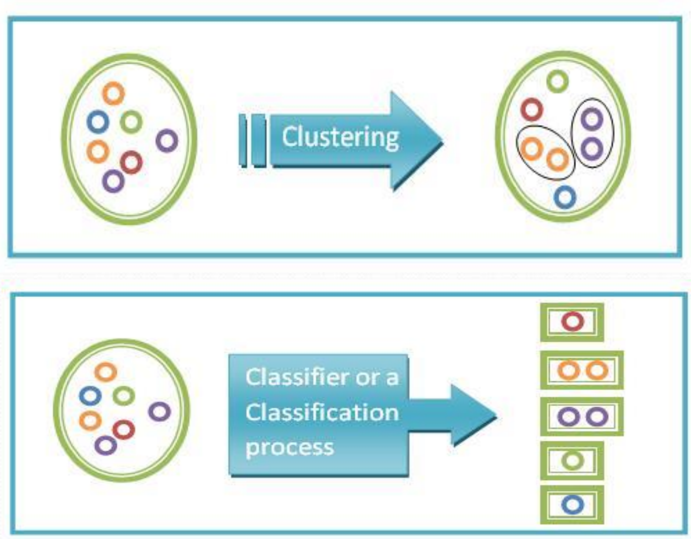
Classification

- Classification is the step of mapping objects to known labels or classes whose side-effect is clustering. Classification requires derivation of classes or training a classifier. (classes are predefined, supervised learning)

Clustering

- Clustering is a way to automatically derive broad patterns or structures from a corpus – sometimes referred to as an unsupervised learning approach. Clustering groups "similar objects" and separates dissimilar objects. (classes are not known)

Clustering vs. Classification

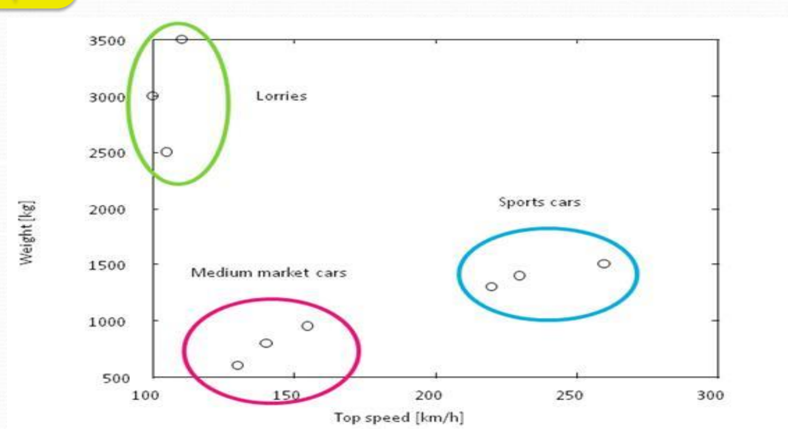


Hard c-means clustering

- Imagine that we have 9 cars (=9 samples, data, points, objects) with their properties as it is shown in the table below:

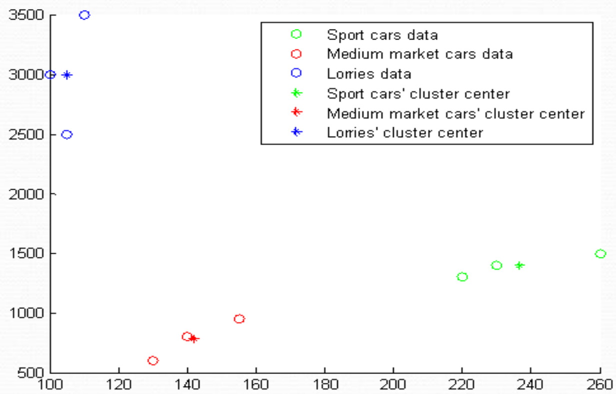
Vehicle	Speed Km/h	Color	Air resistance	Weight Kg
V1	220	Red	0.30	1300
V2	230	Black	0.32	1400
V3	260	Red	0.29	1500
V4	140	Gray	0.35	800
V5	155	Blue	0.33	950
V6	130	White	0.40	600
V7	100	Black	0.50	3000
V8	105	Red	0.60	2500
V9	110	gray	0.55	3500

Hard c-means clustering



- The diagram helps us to realize that those cars can be categorized into three "clusters". Now we can label these clusters: Sport cars, Medium market cars and Lorries according to their weight and speed.

Cluster Center



$$v_{Sport\ cars} = \frac{\begin{bmatrix}220\\1300\end{bmatrix}+\begin{bmatrix}230\\1400\end{bmatrix}+\begin{bmatrix}260\\1500\end{bmatrix}}{3} = \begin{bmatrix}236.7\\1400\end{bmatrix} \qquad \bar{v}_i = \frac{\sum_{j=1}^{n}\mu_{ij}\bar{x}_j}{\sum_{j=1}^{n}\mu_{ij}} \quad \forall i \in \{1,2,..,c\}$$

Clustering criteria

- Similarity is based on distance.
- The criteria proposed for the hard c-means the algorithm is known as a within-class sum of squared errors approach using a Euclidean norm to characterize distance.

$$e_i = \sum_{j=1}^{n}\mu_{ij}d_{ij} = \sum_{j=1}^{n}\mu_{ij}\left\|\bar{v}_i - \bar{x}_j\right\| \quad \forall i \in \{1,2,..,c\}$$

$$E = \sum_{i=1}^{c} e_i = \sum_{i=1}^{c}\sum_{j=1}^{n}\mu_{ij}d_{ij}$$

Bezdek's hard c-mean clustering algorithm

- A mathematical definition of our problem is given here:

$$\min E = \sum_{i=1}^{c}\sum_{j=1}^{n}\mu_{ij}\left\|\bar{v}_i - \bar{x}_j\right\|$$

s.t.

$$\bar{v}_i = \frac{\sum_{j=1}^{n}\mu_{ij}\bar{x}_j}{\sum_{j=1}^{n}\mu_{ij}}$$

$$\sum_{i=1}^{c}\mu_{ij} = 1$$

$$0 < \sum_{j=1}^{n}\mu_{ij} < n$$

$$\mu_{ij} = 0 \; or \; 1 \qquad \forall i,j$$

Bezdek's hard c-mean clustering algorithm

1. Fix $c(2 \le c < n)$ and initialize the U matrix:

   $U^{(0)} \in M_c$

   Then do $r = 0,1,2,\dots$

2. Calculate the c center vectors ($\bar{v}_i^{(r)}$) with $U^{(r)}$.

3. Update $U^{(r)}$; calculate the updated membership matrix (for all i, j):

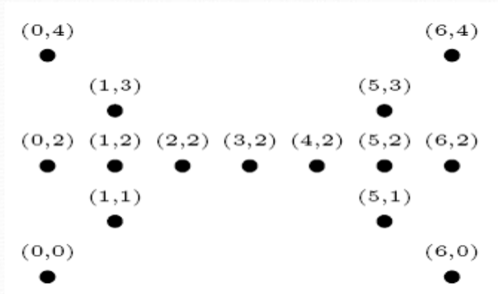
   $$\mu_{ij}^{(r+1)} = \begin{cases} 1 & d_{ij}^{(r)} = \min\left\{d_{kj}^{(r)}\right\} \quad \forall k \in \{1,2,\dots,c\} \\ 0 & otherwise \end{cases}$$

4. If $\left\|U^{(r+1)} - U^{(r)}\right\| \le \varepsilon(tolerance\ level)$

   Stop; otherwise set $r = r + 1$ and return to step 2.

Fuzzy clustering

The butterfly data set



$$U^{(4)} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

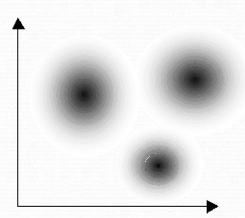
Fuzzy clustering

❖In fuzzy clustering, a single point can have partial membership in more than one class.

$$\mu_{ik} = \mu_{A_i}(x_k) \in [0,1]$$

$$\sum_{i=1}^{c} \mu_{ik} = 1 \quad \forall k \in \{1,2,\dots,n\}$$

$$0 < \sum_{k=1}^{n} \mu_{ik} < n$$



❖Thus for butterfly example we can have:

$$U = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.5 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Fuzzy c-means algorithm

1. Fix $c(2 \leq c < n)$ and select a value for parameter m. Initialize the U matrix:

   Each step in this algorithm will be labeled r, where $r = 0,1,2,\ldots$

2. Calculate the c center vectors ($\bar{v}_i^{(r)}$) with $U^{(r)}$ for each step.

3. Update $U^{(r)}$; calculate the updated membership matrix (for all i, k):

$$\mu_{ik}^{(r+1)} = \left[\sum_{j=1}^{c}\left(\frac{d_{ik}^{(r)}}{d_{jk}^{(r)}}\right)^{\frac{2}{m-1}}\right]^{-1}$$

Distance from point *k* to current cluster centre *i*

Distance from point *k* to other cluster centres *j*

   (if $d_{jk}^{(r)} = 0$ then $\mu_{ik}^{(r+1)} = 0$)

4. If $\left\|U^{(r+1)} - U^{(r)}\right\| \leq \varepsilon(tolerance\ level)$

   Stop; otherwise set $r = r + 1$ and return to step 2.

خوشه‌بندی بر چه اساسی انجام شود

- بر اساس خوشه‌بندی **مقادیر پارامترهای دارای عدم‌قطعیت** اقدام به ادغام سناریوهای شبیه به هم کنیم.

- به ازاء هر سناریو مدل حل شود و بعد بر اساس خوشه‌بندی **جواب‌های مدل** اقدام به ادغام سناریوهای مرتبط کنیم.

- به ازاء هر سناریو مدل حل شود و بعد بر اساس خوشه‌بندی **مقدار تابع هدف** اقدام به ادغام سناریوهای مرتبط کنیم.

نتـــایـج مثال مورد مطالعه

Performance measure

$$SV = \frac{\sum_i \sum_j FCI_{(i,j)}}{n}$$

$$RS(h) = \sum_{k=1}^{n} \left(\mu_h(k).SV(k) \right)$$

RS(h): ranking score of cluster h
n: number of compatible scenarios in each cluster.
μ_h(k): Degree of membership of scenario k to cluster h.

final scenarios and their ranking scores for Gath-Geva and Xie-Beni indexes

Main Final Scenarios	Forecasted trends							RS
	P1	P2	E1	E2	E3	C1	D1	
No.1	Low	Very High	Medium	Medium	Medium	Low	High	21.517
No.2	High	Medium	High	Medium	Very High	Low	High	20.409
No.3	High	Very High	Medium	High	Very High	High	High	19.325
No.4	Low	Medium	Medium	Medium	Medium	High	High	22.188

final scenarios and their ranking scores for Fukuyama-Sugeno index

Main Final Scenarios	Forecasted trends							RS
	P1	P2	E1	E2	E3	C1	D1	
No.1	High	Very High	High	High	Very High	High	High	21.013
No.2	High	Very High	Medium	Medium	Very High	Low	High	19.306
No.3	Low	Very High	Medium	Medium	Medium	Low	High	24.550
No.4	Low	Medium	Low	Low	Medium	High	High	22.735
No.5	High	Medium	Medium	Medium	Very High	Low	High	24.039

سوال و بحث

و آخر دعوانا ان الحمدلله
رب العالمین