A suggested methodology for evaluating the Industrial glass design by using the concept of (Sigma – σ)

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***Abstract*:**

It's well known in all academia of art and design, as well as in the productive institutions, that the evaluation of design is one of the most complicated processes, since being related to the sentiment and variance in needs and cultures from one individual to another, thus the paper is seeking to devise a methodology based on a sensible and rational theory that includes the quantitative measurement and statistical analysis by adopting the concept of Sigma (σ), which goes to calculate the standard deviation (S.) of different criterion to ensure the highest accuracy and less dispersion of results.
Accordingly it was possible to specify the research problem in the need to find a usable methodology to be used in assessing design through a set of criteria, which compose the aspects of evaluation, namely: aesthetics, functional, economical and technical criterions.
The proposed methodology - in question - can be applied in the following domains:

- **a.** The academia which concerned for product design in general, and industrial glass design in particular, where it's useable in selecting the final design/designs.
- **b.** In the productive Institutions in general, and glass production institutions in particular; where the need for selecting the final design/ designs to be manufactured, and/or assessing the performance level of the designer/ designers.

The research assumes that the use of "Sigma" concept can help in devising a methodology for evaluating the industrial design in general and the industrial glass design in particular, in terms of being more convenient for measuring the different types of evaluation criteria.
Eventually the research goes to demonstrate the steps of applying the suggested methodology by conducting the evaluation process of some glass designs.
As for the most important results, it was possible to devise the proposed methodology, which based on using the concept of "Sigma" in calculating the standard deviation (S), and the relative standard deviation (RSD) of the different values that represent the evaluation criteria, in addition to set the evaluation form which includes the suggested criteria to be used in the evaluation process, and the magic form where the calculated values can be placed and recorded, eventually the research goes to apply the devised methodology in a case of evaluating some of glass products.

Key words:
Glass design, design evaluation, standard deviation, sigma concept, relative standard deviation.

Introduction:

This paper is based on the results of a previous research which includes a survey [(2)] on creativity as one of the most important means that lead to uniqueness, and thus enhancing the competitiveness of the glass production institutions in the market; the findings of that survey demonstrates that **(90.9 %)** of the respondents see that creative system which adopts the concept of creativity in all procceses outputs, can inhance the competitiveness of the glass production inistitutions in the market. On other hand it's well known in all academia that the evaluation and assessing of design is considered one of the most complicated processes, in terms of being related to the sentiment and variance in cultures from one individual to another.
Accordingly, it was possible to identify the problem of the research in the need to find a usable methodology to be used in assessing the different sources of design evaluation such as: (aesthetical aspects, functional aspects, economical and technical aspects).
Hence the research aims to devise a methodology based on a sensible and rational theory to obtain more accurate and realistic results in, terms of reducing the dispersion of the measured values and approach the real assessment.

The research assumes that the suggested methodology in question can help in decision making in both educational academia and enterprises concerned about the evaluation (1/185) of the innovative activities outputs such as industrial design in general and industrial glass design in particular.

Thus the research is seeking to devise the suggested methodology by using the concept of "Sigma", which based on calculating the standard deviation (S.) and relative standard deviation (RSD) (8) of different components that represent the criteria of the evaluation process, namely: (attraction and appearance (5/75), function and utility (5/75), price (6/242), supply (6/242)).

And then, the research goes to demonstrate the steps of applying the suggested methodology by conducting the evaluation process of some glass designs.

Terminology and Concepts:

1. Standard Deviation (Sigma - σ):

In probability and statistics, the standard deviation of random variable, or population or multi-set of values is a measure of the spread of its values. The standard deviation is usually denoted with the letter **(σ- sigma)** (4/60). It is defined (3/123) as the positive square root of the variance.

Where:

$$\left.\begin{array}{l} \text{- Sample Standard deviation (S)} = \sqrt{S^2} \\ \text{- Population Standard deviation } (\sigma) = \sqrt{\sigma^2} \end{array}\right\} \quad (1)$$

2. Relative Standard Deviation (RSD) (7):

The relative standard deviation (RSD or %RSD) is the absolute value of the coefficient of variation expressed as a percentage.

It is widely used to express the precision (7) of an assay especially as in this paper, where the variable values comes from different components namely: (Appearance, Function, Price and Supply time), further more the assessment process is hard to be controlled as it differs from a single arbitrator to another due to the variation of culture and self sentiment, thus the research goes to apply the Relative Standard Deviation (RSD).

Where:

Relative Standard Deviation (RSD) (9) = (S) × 100 / (Ẋ)

3. Rationales of using the standard deviation concept:

The use of Standard deviation and (RSD) concepts can help in obtaining the highest accuracy (7) in judging and selecting the best design amongst various designs, where the data sources including random error (7) which result from the variation of the arbitrator's culture and sentiment which varies from one individual to another.

4. Flexible and Critical measuring scale:

The research focuses on (**Likert Scale**) (10) scale as one of the most important types of rating scales and the most commonly used, Thus the research differentiates between the most common intervals of (**Likert Scale**), which used in designing the assessment forms, those most common intervals as termed in this paper are: the (**Flexible Scale)** and the (**Critical Scale**), where:

a. The Flexible Scale:

A type of (**Likert**) scale, which goes to use a wide range of measuring in degrees or points, that ranging from (1: 5) (15) where the value of appraisal increases proportionally according to the increase of number, i.e., the number (5) represents the highest value; Table (1) below, shows an example of the (**flexible Scale type)** as termed in this paper.

It is worth to mention that this type of quantitative measuring system can be converted into a qualitative one (Ranking Assessment), by giving each of the numerical values rated qualitatively such as: (Excellent) to the number (5), and the classification (very good) for the number (4), and so on until the Classification (weak) which refers to the number (1).

b. The Critical Scale:

Another type of (**Likert**) (16) scale, with a narrow range of descriptive answers are used in evaluation, and can be converted from a qualitative to a quantitative type that ranging between (1, 2, 3) (14), by giving the value (3) for each of the higher responds, for example: (Yes - OK - Appropriate - Good ... etc.), while giving the value (1) for each of the lower responds such as: (No - Inappropriate - Bad - Weak ... etc.), eventually the neutral evaluation such: (Don't Know - Not Sure - Somewhat – somehow – Partly – Sort Of ... etc.) will take the value (2); Table (2) shows an example of a **(critical scale type)** as termed in this paper.

Table (1): The flexible scale model where the wide numerical evaluation range from 1:5

Type (1)						
S. No	characteristics	1	2	3	4	5
1-	Appearance & Attraction					
2-	Function & Utility					
3-	Price					
4-	Supply Time					
Type (2)						
S. No	characteristics	1	2	3	4	5
1-	Appearance & Attraction					
2-	Function & Utility					
3-	Price					
4-	Supply Time					
Type (3)						
S. No	characteristics	1	2	3	4	5
1-	Appearance & Attraction					
2-	Function & Utility					
3-	Price					
4-	Supply Time					
Type (4)						
S. No	characteristics	1	2	3	4	5
1-	Appearance & Attraction					
2-	Function & Utility					
3-	Price					
4-	Supply Time					

Table (2): The Critical scale model

Type (1)				
S. No	characteristics	Good	Appropriate	Weak
1-	Appearance & Attraction			
2-	Function & Utility			
3-	Price			
4-	Supply Time			
Type (2)				
S. No	characteristics	Good	Appropriate	Weak
1-	Appearance & Attraction			
2-	Function & Utility			
3-	Price			
4-	Supply Time			
Type (3)				
S. No	characteristics	Good	Appropriate	Weak
1-	Appearance & Attraction			
2-	Function & Utility			
3-	Price			
4-	Supply Time			
Type (4)				
S. No	characteristics	Good	Appropriate	Weak
1-	Appearance & Attraction			
2-	Function & Utility			
3-	Price			
4-	Supply Time			

5. Comparison between the Flexible and Critical Scale:

Table (3) below, shows a comparison between the most common scales used in evaluation as follows:

Table (3): A comparison between the most common scales

	Flex. Scale	Critical Scale
Utilization	Convenient for the evaluation of (ideas) in the Concept Design phase, thus it is more suitable for projects with long-term strategic objectives, where there is much space of time.	Convenient for the evaluation of (Critical & Final) Design short-term strategic objectives, where there is a need for a quick decision-making.
Pros	1- Gives the opportunity to select a greater number of Concept Designs. 2- non-shocking, thus it is encouraging the continuity of the developing.	1- More specific and impartial where there is no room for bias due to limit the extent of the assessment 2- Reduces the time of decision-making in terms of avoiding the hesitancy of the arbitrator, due to the narrow range scale 3- Limits the chances of exaggeration and adjustments of distinguishing by avoiding multiplicity in the higher and lower values of the evaluation scale, therefore it's considered more objective mean of assessment.
Cons	1- Gives the chance for hesitancy due to the wide-range scale, and thus increases the time of the evaluation process. 2- Increase the chances for bias in term of using sentiment in distinguishing a certain design over another.	1- Needs an experienced and competent referee, accordingly the harnessing of this type of scales is limited to certain categories of arbitrators.

According to the comparison above; the research goes to the use of (Critical Scale) type in designing the evaluation model of the suggested methodology in question.

<u>The Suggested Methodology:</u>

This part of the research is seeking to devise the Suggested Methodology by using the concept of the standard deviation which known as **(Sigma – σ)** in calculating the relative standard deviation (RSD.) of different variables that represent the criteria of design under evaluation, namely: (Appearance, Function, Price and Time).

1. Scope and domain of application:

a. The academia of art and design which concerned for the product design evaluation in general, and industrial glass design in particular, where it's useable in selecting the final design/designs.

b. Glass production Institutions:

- Decision making on selecting the best design amongst a set of designs, where the lowest relative standard deviation represents the best design.
- The proposed methodology is useable in assessing the performance level of the designer/ designers in the glass production institutions.

2. Procedures, responsibilities, and forms:

The following figure (1) demonstrates the flow of the evaluation process, in addition to the responsibilities and the forms to be used.

The flow chart - in figure (1) - above shows the streaming of the evaluation process with taking in account the following considerations:

a. for the Preparation and convention of the evaluation session, the organization shall assign an authorized person who carries out the following tasks:

- The preparation and invitation for the evaluation session.
- The process of displaying the Design/designs under evaluation and the distribution of assessment forms.
- collecting records when the evaluation is done.
- Write the minutes of the evaluation session with results after calculation.
- The declaration of evaluation results to the involved members, and
- wrap up of the session.
- Report the results to the top management for decision making and approval.

b. The invitation shall include predefined objectives of evaluation, date and venue of the session convention, in addition to the basic data of the design/designs that intended to be evaluated.

c. The number and quality of representative stakeholders that forms the session members depends on the evaluation objectives.

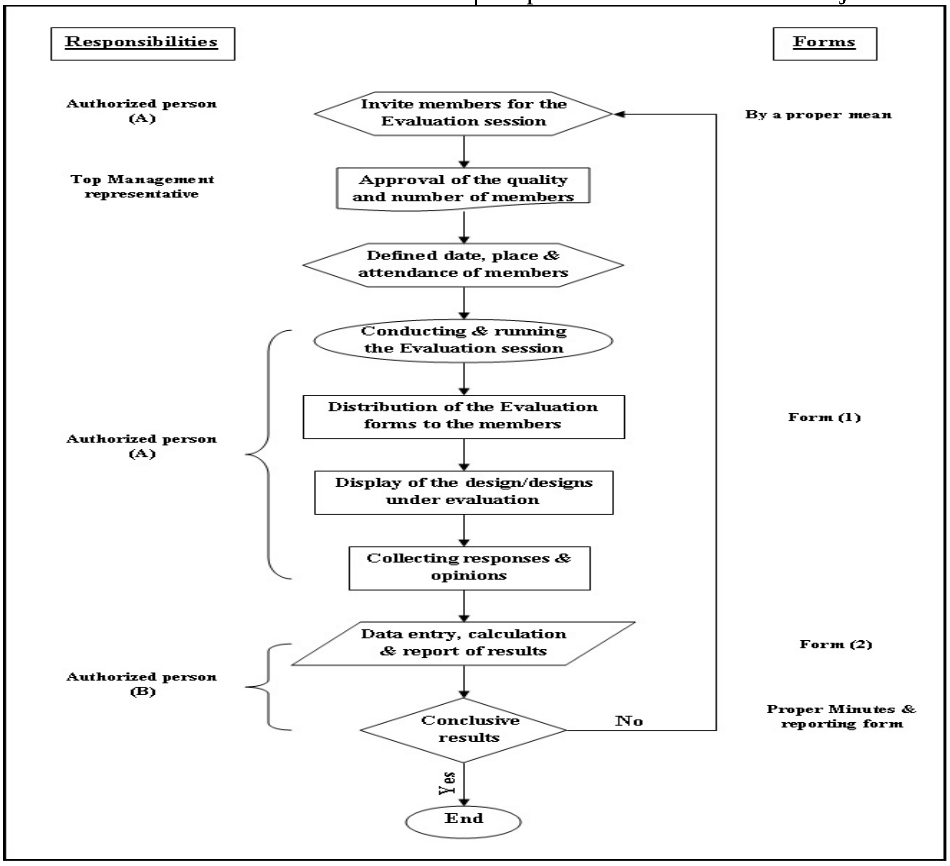


Figure (1): The streaming of the evaluation process

Where:

● In case of final design selection in Art and design academia:

- Course Professor / professors.
- Design makers/makers.
- Selection of External member / members from amongst the experienced personnel in relevant sectors.

● In the case of evaluation the industrial design in glass production enterprises, the organization shall invite the stakeholders, namely:

- The owner/owners or a representative person.
- A representative of top management.
- Representatives of the relevant departments, for example: (financial, production, and Supply chain, etc...).
- Senior Designer / Designers who prepare designs.
- Representatives of stakeholders from outside the organization such as: (customers - suppliers).

d. Start and running the session through the following steps:

- Display designs or prototypes that represent the designs under evaluation using "Wall Walk Method", or any of the appropriate means of display, such as: (Perspective, Photographic shots, embodied prototypes, computed multi media, etc… of display means), taking in account the proper labeling of each design.
- Recording the evaluation by using the form in the previous table (2), where each member can place his/her assessment.
- Avoid discussion that may affect positively or negatively on the opinion of members.
- An authorized person shall carry out the calculation* and computing of results.

Where:

- Classify the Designs in groups, as shown in figure (2).
- Convert from the ranking system (Good, Appropriate and Weak) to the quantitative system by giving numerical values to each response according to the following table (4):

Table (4): Numerical values of each response

Response	Good	Appropriate	Weak
Value	3	2	1

- Calculate the average ($\dot{X}$) of each criterion, namely: (appearance, function, price and time), separately by using the (AVERAGE) function, as demonstrated in table (6), where:

Average ($\dot{X}$) = $\Sigma (V_1+V_2+V_3+\ldots+V_N)$ / Number of Values **(3)**

- Calculate the standard deviation (S.) (8) for each criterion by using the (STDEV.) function, as demonstrated in table (6), where:

$$STDEV\ (S) = \frac{(V_1-\dot{X})^2+(V_2-\dot{X})^2+(V_3-\dot{X})^2+\ldots+(V_N-\dot{X})^2}{N-1} \quad (4)$$

When:

(N) = Number of values

- Calculate the relative standard deviation (RSD) (12) of each criterion (C), by using the following equation:

RSD % = (Standard deviation of criterion C) × 100 / (average of criterion C) **(5)**

***i.e.:* RSD %** = $(S_C) \times 100 / (\dot{X}_C)$ **(6)**

- The total sum of all (ΣRSTD) for the whole factors (Appearance, Function, and Price and Supply time) is the RSD which represents the final design evaluation in percentage.
- The less (ΣRSTD %) is the best design, where the less random error.

e. Session wrap up and closure:

In this process the authorized person who's responsible for coordinating the session shall carry out the following tasks:

- Declares results and resolution.
- Takes the signatures of the members to approve the session minutes.

The next part of this paper is addressing a case of evaluating four glass vases to assign the best of them; by applying the method above to the criteria that composing the aspects of design evaluation, namely: (appearance, function, price and time).

<u>Case study & application:</u>

In this part; the research goes to study a case of decision making by applying the suggested methodology to evaluate four different prototypes of glass vases, where each prototype is representing a certain design, and that with the purpose of selecting the best design.

1. **Evaluation of Some Prototypes of glass vases:**

The following are four prototypes of glass vases; as shown in figure (2), where each prototype is representing a design of a "Vase" under evaluation, with the purpose to:

a. Elect the best design for the implementation at the mass production level.

b. Assess the performance of the designer/designers team, by which the best design was innovated.

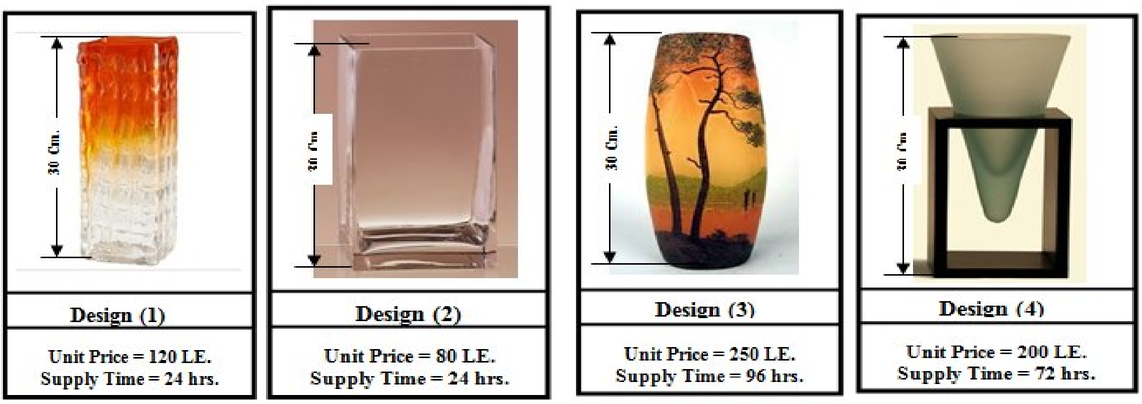


Figure (2): An illustration of the prototypes under evaluation

<u>2. Steps of evaluation process:</u>

Step (1): Collecting Data:

The data are collected during the display of products under evaluation, by using the (Photographic means) as shown in figure (2) above, which represents the designs under evaluation and by harnessing the evaluation form in the previous table (2).

Step (2): Data Entry, Shifting and Calculating:

In the case study of this paper the results are recorded, calculated and demonstrated by using the magic form in table (5).

Step (3): Recording & Calculation of results

The results are calculated by referring to clause 2.d., of the suggested methodology procedures, where the equations (3, 4, 5, 6) are used to calculate the required values, and it is worth to mention that the use of the "Excel" functions is very helpful in this stage; Table (6) shows the records, by using of the magic form in table (5), and demonstrating the results of the case study, as follows:

According to the results below, the lowest (Σ.RSD %) = 58 %, which belongs to (Desig-1), that labeled as (Type-1) and refers accordingly it is considered the best design amongst the four designs under evaluation.

The graph in figure (3) below is a schematic representation of the evaluation results, while the figures (4),(5),(6) and (7) show the comparative schematic of the Mean (Ẋ) and the Standard Deviation (S.) for each criterion that contributes in forming the aspects of the evaluation.

Table (5): Magic form of data entry, shifting and calculating of result

	V. 1	V. 2	V. 3	V.4	V. 5	$\bar{x}$	S.	S. Approx	RSD. %
	Type-1 = Prototype represents Design ( )								
Appearance									
Function									
Price									
Supply Time									
								Σ.RSD %	
	Type-2 = Prototype represents Design ( )								
Appearance									
Function									
Price									
Supply Time									
								Σ.RSD %	
	Type-3 = Prototype represents Design ( )								
Appearance									
Function									
Price									
Supply Time									
								Σ.RSD %	
	Type-4 = Prototype represents Design ( )								
Appearance									
Function									
Price									
Supply Time									
								Σ.RSD %	

Where:

V1: V5 = the values given by each arbitrator.

Ẋ = Average (mean).

S. = the Standard Deviation.

S. Approx. = the approximation of (S.).

RSD % = the relative Standard Deviation in percentage form.

Σ.RSD % = sum of relative standard deviations

Table (6): Recording & calculation of results

	V. 1	V. 2	V. 3	V.4	V. 5	Ẋ	S.	S. Approx	RSD. %
	Type-1 = Prototype represents Design (1)								
Appearance	3	3	3	3	3	3	0	0	0%
Function	3	3	2	3	2	2.6	0.54772256	0.55	21.15%
Price	3	2	2	2	2	2.2	0.4472136	0.45	20.45%
Supply Time	3	3	2	3	3	2.8	0.4472136	0.45	16.10%
								Σ.RSD %	58%
	Type-2 = Prototype represents Design (2)								
Appearance	3	2	2	2	1	2	0.70710678	0.71	35.50%
Function	3	1	2	3	2	2.2	0.83666003	0.84	38.90%
Price	3	2	1	2	2	2	0.70710678	0.71	35.50%
Supply Time	3	3	2	2	2	2.4	0.54772256	0.55	22.90%
								Σ.RSD %	132.80%
	Type-3 = Prototype represents Design (3)								
Appearance	3	3	3	3	2	2.8	0.4472136	0.45	16.10%
Function	3	3	3	3	3	3	0	0	0%
Price	2	3	3	3	1	2.4	0.89442719	0.89	37.10%
Supply Time	1	3	3	2	2	2.2	0.83666003	0.84	38.90%

								Σ.RSD %	92.10%
	Type-4 = Prototype represents Design (4)								
Appearance	2	3	2	3	3	2.6	0.54772256	0.55	21.20%
Function	2	3	1	3	3	2.4	0.89442719	0.89	37.10%
Price	1	3	2	2	2	2	0.70710678	0.71	35.50%
Supply Time	2	3	2	2	2	2.2	0.4472136	0.45	20.50%
								Σ.RSD %	114.30%

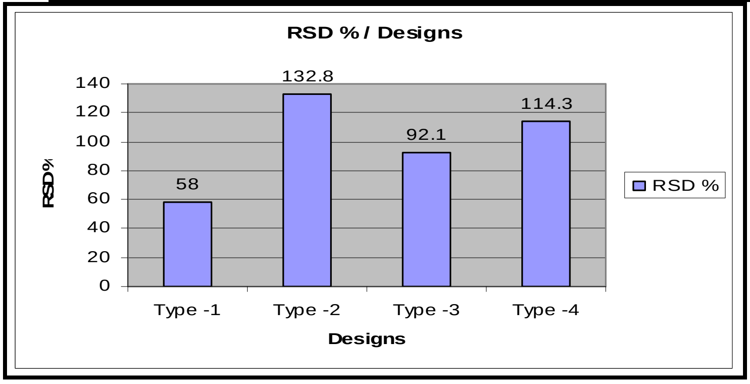
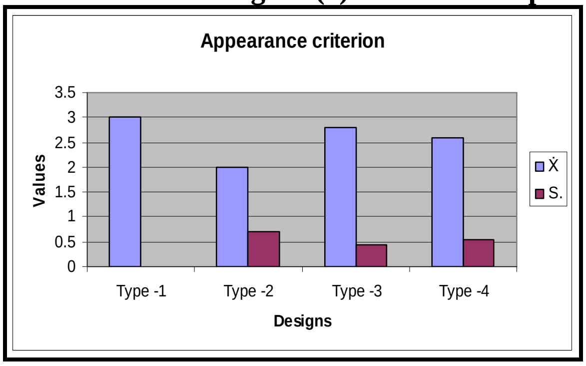
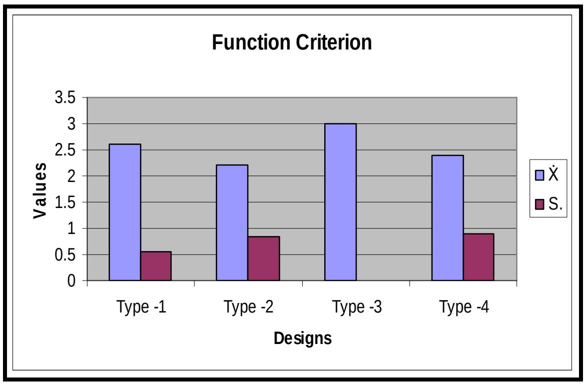


Figure (3): Schematic representation of the evaluation results



Design	Ẋ	S.
Type -1	3	0
Type -2	2	0.71
Type -3	2.8	0.45
Type -4	2.6	0.55

Figure (4): Ẋ & S. Values of appearance criterion

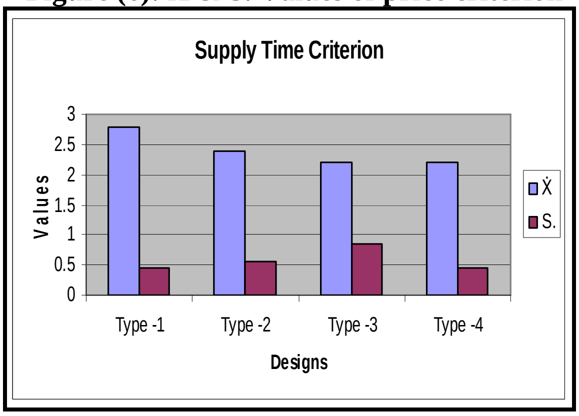


Design	Ẋ	S.
Type -1	2.6	0.55
Type -2	2.2	0.84
Type -3	3	0
Type -4	2.4	0.89

Figure (5): Ẋ & S. Values of function criterion

Design	Ẋ	S.
Type -1	2.2	0.45
Type -2	2	0.71
Type -3	2.4	0.89
Type -4	2	0.71

Figure (6): Ẋ & S. Values of price criterion



Design	Ẋ	S.
Type -1	2.8	0.45
Type -2	2.4	0.55
Type -3	2.2	0.84
Type -4	2.2	0.45

Figure (7): Ẋ & S. Values of time criterion

Findings and discussion:

1. According to the theoretical frame of this paper, it was possible to stand on the definitions of the Standard deviation and relative standard deviation, in addition to the definition of the most common types of scales used in evaluation.

2. The tables (1) and (2) respectively, demonstrate the two common scales, namely: (the flexile and the critical) scales as termed in this paper, by using them in designing two suggested types of evaluation forms according to the criteria which assigned in this paper. Also it was possible to specify the proper evaluation scale to be used in applying the suggested methodology in question, through the comparison between the most common types of evaluation as in table (3).

3. Devise the proposed methodology, on basis of a mathematical and statistical theory by calculating the standard deviation (S), and the relative standard deviation (RSD).

4. It was possible to set the evaluation form which used in the stage of collecting data, as demonstrated in table (2), which includes the suggested criteria to be used in the evaluation process, namely: appearance which represents the aesthetical criterion, function for the utility of the product, price as an economical criterion and eventually the time of supply which indicates the availability of the product.

5. Assign the framework for the proposed methodology, namely: (scope, procedures, responsibilities, and the suggested forms to be used), in addition to providing a flow chart for the steps applying the proposed methodology as in figure (1).

6. The suggested methodology was applied to evaluate a set of some glass products which illustrated in figure (2), with the purpose of selecting the best design according to the research concept, by using the devised magic form that shown in table (5) which includes cells to place the whole values needed in the calculation and recording of results, such as: the average ($\dot{X}$), standard deviation (S), relative standard deviation (RSD), sum of relative standard deviation (ΣRSD).

7. According to the research concept, the research goes to select the design (No.3) which labeled (Type-3), as the best design amongst the other designs (1, 2 and 4) respectively, in terms of it's being the lowest (Σ.RSD), and figure (3) shows the schematic representation of the evaluation results.

8. the concept of this research was demonstrated through the graph in figure (6), which represents the values of the mean and the standard deviation of the price criterion; this chart shows that the design labeled (Type -1) has the lowest standard deviation (S.= 0.45), which considered the best value according to this research; since the weighting of the suggested methodology is based on the value of the standard deviation regardless the value of the mean.

Recommendations:

As this method is considered a new trend in evaluating innovation and creative activity such as design, thus the more empirical studies to calculate the uncertainty is highly recommended.

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