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Combination VIKOR Modeland Measurement Systems Analysis (MSA)

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Abstract

One of the basic principles of any organization is to assure about obtained figures of its products measurement. If the measured data is not trusted, the possibility of wrong decisions regarding the approval or rejection of products and obviously the cost would be great. First cases in measurement systems analyses which cross minds are criteria for approval or rejection for any measurement system use its obtained results. It seems that comparing and ranking different measurement systems have an important role in future of any organization, when every system is evaluated by common criteria in measurement systems analysis. MCDM methods can greatly influence decision quality. Although, some limitations has been seen in the description of criteria or sub-criteria information in classical VIKOR under linguistic environment, which result in the loss and low rate of accuracy of information. Therefore, to solve that problem VIKOR method has been developed by many researchers. In this paper, the rank of different measurement systems as an alternative, average attribute and calculated index is considered as a benchmark in measurement systems analysis. For this purpose, a multiple criteria decision-making model of VIKOR method has been presented. In order to determine the Attribute weight, an AHP method has also been used before VIKOR.In order to fully consider the relative importance of the criteria, and create a balance between total and individual satisfaction the VIKOR method is applied to aggregate the whole criteria. The extended VIKOR can rank and select the best one from a set of alternatives.

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Introduction

Measurement systems analysis (MSA) is the most important issue that must be done before any action. One of basic principle of any organization is to assure about obtained figures of its products measurement. If the measured data is not trusted, that will lead to a wrong decision regarding the approval or rejection of products and obviously the cost would go up. Obtained figures from processes are usually compared and calculated within statistics framework, and are corrected in case of being out of control (Automotive Industry Action Group, 2002). The result may also be used to determine the correlation of two or more variables. For instance, the most important partof molding may have considerable relation with temperature and initial amount of template used by analysis system. Decision-makings are the essence of all managerial activities and are divided into two categories of multi Attribute and multi objectives, while each category has several different methods to solve problems. The selection of one of them over the others is depended on the type of problem, researcher's opinions and experiences. Ranked auditors are an efficient step to increase products' quality. A decision-making and ranked contractor is one of management's main duties. Also, comparison of different measurement systems could be very helpful in selection of relevant contractors in order to reduce the risk of production or decision- making. To achieve that, the application of different multiple criteria decision methods has been employed in measurement systems analysis. VIKOR (which stands for 'VlseKriterijumskaOptimizacija I KompromisnoResenje,' meaning multi-criteria optimization and compromise solution) is one of the classical MADM methods of decision making and was developed based on L.P metric method by Opricovic (1998). It is regarded as an efficient tool to find a compromise solution out of a set of conflicting criteria (Qin et al., 2015). In this method, the decision maker takes a VIKOR coefficient to create balance between L.P metric method when $p=\infty$ and $p=1$.

MCDM has been widely studied by researchers and practitioners as one of the research areas of operations research and management science.With respect to decision maker(s) preferences itdeals with evaluating, assessing and selecting alternatives from the best to the worst under conflicting criteria. The main characteristics of an MCDM method include: (1) decision alternatives, (2) decision criteria against which the alternatives are evaluated, (3) scores that reflect the value of an alternative's expected performance on the criteria, and (4) criteria weights that measure the relative importance of each criterion as compared with others (Celik et al., 2012). Several MCDM methods have been proposed by researchers. As an MCDM method VIKOR can rank alternatives and determine the compromise solution that is the closest to the "ideal". By adding the recent VIKOR applications and regarding to the rapid increase in applications of VIKOR among other MCDM methods, this

studyaimedat making the review to contribute to the literature.

The remainder of this paper is organized as follows: Section 2 reviews the literature related to measurement systems analysis. The criteria are calculated and presented in section 3. MCDM and VIKOR techniques, and the main contributions of this paperare described in section 4; the application of VIKOR model in measurement system analysis is included in section 5 and finally suggestions and conclusions are drawn in the final section (Section 6).

Literature Review

In 18thand 19thcentury quality control was not similar to what exists today. Different components were assembled by hand and final inspection was done by the worker. In the early 1900s Frederick W.Taylor, known as the leader of scientific management, regulated the inspection through separation and allocation as one of the eight essential tasks, for effective workshop management. In 1931, quality revolution happened and was regarded as a turning point. Shewhart(1931) wrote a book named "Economic Quality Control of Products". He and Harold Dutch and Deming and Jordan had a significant role in statistical quality control development. Shewhart(1931) found out that variability (volatility) is an undeniable fact in industrial life. These changes were recognizable by statistic and probability principles. At the same time, other researchers, e.g. Harold Dutch and HariRomic have developed sampling. Second World War had considerable effect on S.Q.C development. In December 1940, U.S war department established a committee to essay quality standards that focused on development and utilization of control charts, which was published in 1941 and 1942. At this time AQL tables were developed (AQL was accepted as poor quality, in other words maximum percent of defective is accepted by a supplier). In October 1945, thirteen persons (members of the war quality control) organized society of quality engineering that merged with another federation next year, and created American society for quality control (ASQC) that still exist till now. Meanwhile, first American journal was named Industrial Quality Control which was published by Buffalo 0.

Society quality control engineers in June 1944, later it was named Quality Progress, formal journal of ASQC. Based on statistics, Quality Control was known and developed as a field of education and by the end of 1940. In 1950's comparative standard was increased with requirements of mass production. In 60's, 70's and 80's, the concept of quality was completed by "adaptation for using and cost" and "adaptation with last need". In 1987, General Motors was the first company which provided guidelines for measuring system's ability. Ford presented additional guidelines in 1989. In Germany, Robert Bush group published a guideline (to determine the ability of measurement system under actual operating conditions) in 1990. In 1994, Mercedes-Benz published other guidelines in this regard. The differences between these guidelines led to additional problems and needs for resources suppliers.

A reference was needed to improve this situation and standardize the guidelines, which include all technical report format and terms, information, and designing. Therefore, Chrysler, Ford and General Motors decided to establish common guidelines, providing reference book for measurement systems analysis for the first time. ASQ under Industrial Association of American Machine guaranteed its enforcement. In 1995, the second edition published and contradictions between this handbook and Mercedes Benz guidelines were considered. In 2002 the book was reviewed by the same team for third time and published. In the introduction of this book the following phrase has been stated: "This book is not intended to limit development of analysis for particular process or production". These question and answers were presented to customers who work in quality section.

Chang and Hsu (2009) applied a ranking strategies model with use of limited resources and VIKOR method. The VIKOR method was proposed to solve MCDM problems with conflicting and non-commensurable (different units) criteria, assuming that compromising is acceptable for conflict resolution.The decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria" (Opricovic&Tzeng, 2007). Opricovic (1998) developed the initial VIKOR method. The VIKOR method is the optimization and compromise solution in MCDM, which is appropriate for estimating each alternative for each criterion (Opricovic, 1998;Opricovic&Tzeng, 2002; Opricovic&Tzeng, 2004; Opricovic&Tzeng, 2007; Huang et al., 2009). This method can be appliedin the complex multi-criteria systems(Opricovic&Tzeng, 2004). The extended VIKOR method was developed and compared with TOPSIS,PROMETHEE, and ELECTRE (Opricovic&Tzeng, 2007).

Tong et al. (2007) optimized multi response process with VIKOR. Wu et al. (2008) applied VIKOR to evaluate electronic equipment. Dai et al. (2007 &2008) used VIKOR in fuzzy environment to select supplier in supply chain. Buyukozkan, Ruan, (2008) used a fuzzy decision-making approach to evaluatesoftware development projects by use of VIKOR method. Liu and Du (2008) used VIKOR to select supplier with criteria combinatorial approach. Lin et al. (2008) used VIKOR to choose commercial partners to innovate technological strategic alliance. Chang et al. (2008) proceeded to evaluate supplier's selection in supply Chain using VIKOR. Kong et al. (2008) applied fuzzy VIKOR in technical innovation. Chen and Wang (2009) used Fuzzy VIKOR to optimize contractor's selection in IT systems' outsourcing project.Yuansheng& Ying (2008) applied VIKOR in the study of credit risk in energy organizations by useof Fuzzy VIKOR.Sayadi et al. (2009) proposed an integrating VIKOR with interval numbers. Opricovic (2009) applied VIKOR to present a compromise solution planning water resources. Chiang (2009)presented an online decision support system by using fuzzy VIKOR.Wu et al. (2009) applied VIKOR to evaluate banking performance based on scorecard. Liu & Chuang(2010) presented a hybrid multi criteria model for supplier's

selection in outsourcing. Sanayei et al. (2010) used VIKOR technique to select supplier in Fuzzy conditions with group decision-making.Mohaghar et al. (2012) used FAHP and VIKOR method in selecting marketing strategy.

Jahan and Edwards (2013) developed VIKOR to interval numbers for material selection; Kuo and Liang (2001),Bazzazi et al. (2011) and Rezaie et al. (2014) proposed extended VIKOR with triangular fuzzy number for MCDM problems. Girubha and Vinodh (2012) integrated trapezoidal fuzzy number with VIKOR to select the best material of an automotive component; and Ju and Wang (2013) extended VIKOR to trapezoidal fuzzy number to solve MCDM problems. Lia et al. (2015) proposed a new risk evaluation methodology for FMEA based on combination of weighting and fuzzy VIKOR method to deal with the risk factors and identify the most serious failure modes for corrective actions.

Mandalet al. (2015) believe the incorporation of fuzzy VIKOR technique enables us to develop a ranking mechanism for the failure modes where the individual constituent components are non-commensurable in nature. The developed ranking mechanism helps the decision makers in optimal allocation of safety critical resources used for risk mitigation purposes.

Zhu et al. (2015) developed a systematic approach to manipulate the vagueness and subjectivity to enhance the objectivity in design concept evaluation by combinationof rough number, analytic hierarchy process (AHP) and compromise ranking method(VIKOR).

Materials and Method

To support decision making processes, numerous models have been established throughout the years. As one of the research areas of operations research and management science,multi criteria decision making (MCDM) can find compromise solution for evaluating and ranking alternatives from the best to the worst under conflicting criteria with respect to decision maker(s) preferences. It has been widely studied by researchers and practitioners. Therefore, MCDM methods have great impacts on decision quality.

The VIKOR; that means multi- criteria optimization and compromise solution continues to be applied satisfactorily across different application areasin a compromise approach. However, there are some limitationsin the information description of criteria or sub-criteria under linguistic environmentin traditional VIKOR, which result in the loss and low rate of information accuracy. To solve that problem the extended versions of VIKOR have been proposed by many researchers.

In this paper, VIKOR integrated Measurement Systems Analysis for selection of the most appropriate Measurement Systems Analysis. The main contributions of this paper are:

- There is no domestic investigation of Measurement Systems Analysis using extended VIKOR under linguistic information.

- The proposed method can promote the accuracy and quality of decision-making.
- The decision process and management efficiency can be improved.
- Utilization of criteria and calculate them

All criteria were obtained from reference duo to its completion (Automotive Industry Action Group, 2002)

- Bias

Bias is the difference between collected data $(\overline{X})$ and actual size of measured component (X_R)

$$Bias = \overline{X} - X_R \quad (1)$$

- Repeatability

EV is equal to distribution of measurement system while an investigator measured a part while using a tool frequently.

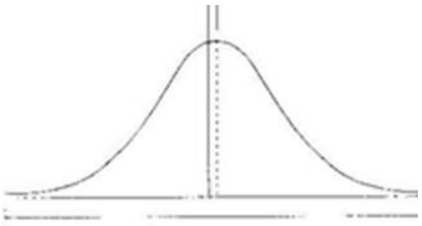

Figure 1. Repeatability

$$EV = 5.15 \frac{\overline{R}}{d_2^*} \quad (2)$$

- Reproductively

AV is equal to distribution of changing any factor in measurement system such as operator, method, tool,so forth that obtained by measuring a part frequently. AV is calculated as follows:

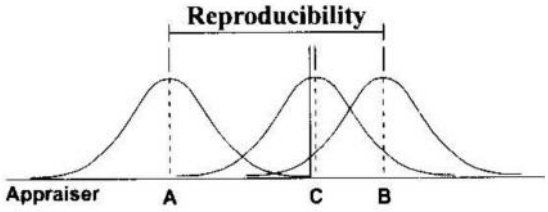

Figure 2. Reproducibility

$$AV = \sqrt{\left[5.15 \frac{\overline{X}_{DIF}}{d_2^*}\right]^2 - \frac{EV^2}{n.r}} \quad (3)$$

$$\overline{X}_{DIF} = Max\overline{X} - Min\overline{X} \quad (4)$$

- Part to part variation

Part to part variation is equal to distribution of used part in sampling. Therefore, parts must be chosen from all range of process and have covered range of tolerance. Thus,the deviation of selected parts would be equal to the deviation of process. PV value is calculated as follows:

$$PV = 5.15 \frac{R_P}{d_2^*} \quad (5)$$

- Gage Repeatability & Reproducibility (R&R)

That will be equal to the sum of repeatability and reproducibility and is obtained from the following equation.

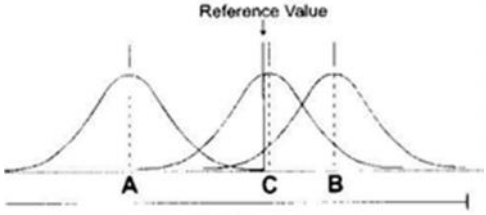

Figure 3.R&R(Gage)

$$R\,\&\,R = \sqrt{EV^2 + AV^2} \quad (6)$$

R&R indicates the range of tolerances in measurement system.

- Reference Factor

R&R must be divided by reference factor and based on the result we can comment about system qualifications or disqualifications.

$$R\,\&\,R\% = \frac{R\,\&\,R}{RF} \times 100\% \quad (7)$$

- Ability of resolution (NDC)

This indicator refers to minimum detectable interval in measurement system. If the system is not able to distinguish appropriately, it means thatit cannot investigate changes in measuring parts. If value is less than 2, system is not suitable;otherwise if the value is equal to 2,then the figures swing up and down, so this system is suitable only for inspection.

Resolution is calculated as fallow:

$$NDC = \frac{PV}{R\,\&\,R} * 1.41 \quad (8)$$

- Ability of measurement tools (C_g , C_{gk})

Inherent variability of measurement tool isassessed by calculating this parameter. C_g (Correctly) and C_{gk} (accuracy) are used to evaluate repeatability and reliability of measurement tools simultaneously. These parameters were applied for new or fixed tool and also approval of a measurement method.

$$C_g = \frac{0.15 \pm_P}{S_g} \quad (9)$$

$$C_{gk} = \frac{0.45 \pm_P - \left|\bar{X}_g - X_m\right|}{3S_g} \quad (10)$$

Multi-criteria decision-making with VIKOR method

VIKOR is a MultipleAttribute Decision Makingagreement method and was developed based on LP-metric method(Wei & Lin, 2008).

$$L_{pi} = \{\sum_{j=1}^{n} [W_i (f_j^* - f_{ij})/(f^* - f_j^-)]^p\}^{1/p}$$

$$1 \le p \le +\infty; i = 1, 2, \dots, I \quad (11)$$

This method could provide a maximum utility group for majority, and a minimum individual regret for opposition. The process includes the following steps (Wei & Lin, 2008)

1- Calculate the normalized values:

If m is alternative and n is attribute, normalized process values where X_n is the real value of I'thj'th would be:

$$f_{ij} = X_{ij} \Big/ \sqrt{\textstyle\sum_{j=1}^{n} X_{ij}^2}, \quad (12)$$

$$i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

2- Determine the best and worst values:

We find the best and worst values of any criteria and define f_j^* and f_j^-, respectively.

$$f_j^* = Max\ f_{ij}, i = 1, 2, \dots, \text{m} \quad (13)$$

$$f_j^* = Min\ f_{ij}, j = 1, 2, \dots, \text{n} \quad (14)$$

3- Determine the weight of criteria

The weights of attributeare calculated in order to express important relationship. In this paper, VIKOR method was used for performanceevaluation (Saaty, 1980).

4- Calculation of S_i andR_i

These parameters are obtained as follows:

$$S_i = \sum_{j=1}^{n} W_i\,(f_j^* - f_{ij})/(f^* - f_j^-) \quad (15)$$

$$R_i = Max[W_i(f_j^* - f_{ij})/(f^* - f_j^-)] \quad (16)$$

5- Calculate the amount of VIKOR

It is defined for each I as follows:

$$Q_i = V\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - V)\left[\frac{R_i - R^*}{R^- - R^*}\right] \quad (17)$$

$$S^- = \text{Max}\, S_i,\ S^* = Min\ S_i, R^- = Max\ R_i, R^* = Min\ R_i$$

And V that is weighting strategy of the majority agreed criteria or maximum utility group.

6- Ranking the alternatives based on the values

In this step, the alternatives are ranked and the decision is making based on the calculated values in previous step. The alternative which had fewer Q,will be a top priority.

Case study

Sazehgostar Company wants to prioritize its contractors based on their measurement system ability, in order to outsource a part of produced components that is considered a more sensitive part (parts that need to be accurate). Therefore, the four selected contractors wereevaluated by BIAS, R&R, NDC, C_g , C_{gk} indices.

First weight of criteria obtained through a pair of comparisons and different system score were calculated based on any dimension. Comparisons were done by standard AHP questionnaire (Saaty, 1980) and the results have formed a matrix of paired comparisons. Table 1 shows the calculated weights by AHP in which geometric average approach is used to combine comparisons based on experts' opinions. The results of measurement system analysis are shown in table 2 and the normalized values aregiven in table 3. Finally, $R_i$and $S_i$are calculated in table 5.

Table 1- Calculated weights by AHP

Rows	Criterion	Calculated weights by AHP
1	BIAS	0.178
2	R&R%	0.366
3	NDC	0.152
4	ز	0.152
5	C_{gk}	0.152

Table 2- ObtainingMatrix by Calculation in MSA

Criterion / Alternatives	BIAS	%R&R	NDC	C_g	C_{gk}
Datise company's measurement system	0.04	25	6	1.39	1.36
Fafco company's measurement system	0.1	18	8	1.49	1.42
NikanPishe company's measurement system	0.06	28	5	1.77	1.74
Delta company's measurement system	0.08	24	10	1.35	1.32

Table 3- The normalized matrix

Criterion / Alternative	Absolute value BIAS	%R&R	NDC	C_g	C_{gk}
	Negative Criterion	Negative Criterion	Positive Criterion	Positive Criterion	Positive Criterion
Datise company's measurement system	0.272166	0.520269	0.4	0.460588	0.462789
Fafco company's measurement system	0.680414	0.374594	0.533333	0.493724	0.483206
NikanPishe company's measurement system	0.408248	0.582701	0.333333	0.586504	0.592097
Delta company's measurement system	0.544331	0.499458	0.666667	0.447334	0.449177
Weight	0.178	0.366	0.152	0.152	0.152
f^*	0.272166	0.374594	0.666667	0.586504	0.592097
f^-	0.680414	0.582701	0.333333	0.447334	0.449177

Table 4- Calculation of $w_i(f_j^* - f_{ij})/(f^* - f_j^-)$

	BIAS	%R&R	NDC	C_g	C_{gk}
Datise company's measurement system	0	0.2562	0.1216	0.137524	0.137524
Fafco company's measurement system	0.178	0	0.0608	0.101333	0.11581
NikanPishe company's measurement system	0.059333	0.366	0.152	0	0
Delta company's	0.118667	0.2196	0	0.152	0.152

measurement system

Table 5- Result of VIKOR method in case study

v	0.5							
Alternative	S_i	R_i	S^*	S^-	R*	R^-	Q_i	Grade
Datise company's measurement system	0.652848	0.2562	0.455943	0.652848	0.178	0.366	0.707979	3
Fafco company's measurement system	0.455943	0.178					0	1
NikanPishe company's measurement system	0.577333	0.366					0.808247	4
Delta company's measurement system	0.642267	0.2196					0.58377	2

Table 5 shows model results.V coefficients for all options are assumed 0.5. According to the results of this study, FafcoCompany has the best measurement system.The Next ranks belong to Delta Company, DatiseCompany and NikanpisheCompany respectively.

Conclusion

The main objective of this study was to compare different measurement systems calculate alternatives in MSA and identify the best measurement system. To compare different alternative measurement systems, VIKOR multi-criteria decision method was applied in this study. Toavoid the unqualified MSAs to participate in the selection from beginning to end, the unqualified ones will be excluded in an early stageby designing the two-phase method. So, the tasks related to the unqualified MSAs can then be substantially decreased. Therefore, the final selected MSA must conform to the fundamental requirements.

Due tothe vague knowledge of experts about the preference of one alternative over another, and failing to estimate their preferences with exact numerical values, it is complex or ill-defined to be amenable for description in conventional quantitative expressions. Hence, some studies have focused on the subjectiveness and imprecision of humans' behavior and the uncertainty and imprecise numeric values of decision data. For example, the VIKOR has been extended to solve hospital service evaluation problems with uncertain conditions; since it can deal with clear-cut/ uncertain data simultaneously.

The results showed thatFafcosystem has the highest priority. The weights of criteria were calculated by the use of AHP and VIKOR method was employed for ranking. Other criteria and alternatives of MSA could be used in future. Other methods such as average weighted, TOPSIS, ELECTRE, PROMETHEE could be used. Also, Fuzzy numbers or Grey numbers could be used for accurate estimation of output values in

different decision making environments and conditions.

All in all, this proposed extended method can be utilized to solve the comprehensive and multi-constrained optimal selection problem with clear and effective management process. The two-phase extended method will show good practicability and advantage for the industry which needs to focus on some specific criteria. The managers should pay more attention to the suitability of the methods and the efficiency of management process in the practical management problems.

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