



Fuzzy Measurement System Analysis Approach: A Case Study

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Abstract

In quality control, gathering relevant and timely data is essential to monitor and determine process variation. Since process data are obtained through measuring instruments that contain uncertainties, an ideal measurement system that has a statistical characteristic of zero error does not exist. Measurement System Analysis (MSA), one of the requirements of ISO/TS 16949, is an experimental and mathematical method of determining the variation arising from measurement systems rather than from a process or product. MSA is used to minimize the risk of wrong decisions regarding process control. Recently, the fuzzy approach has been utilized to cope with the vagueness of the obtained data in MSA studies. This paper analyzes the use of Fuzzy MSA in a company that manufactures automotive parts.

Key Words

Measurement System Analysis (MSA), Fuzzy Approach, Fuzzy MSA, Gage Repeatability and Reproducibility (GR&R), Number of Distinct Categories (NDC).

1. Introduction

In today's competitive environment, companies are trying to provide services and products that can meet basic customer demands in the most profitable way. Under the ongoing concept, the customer's demand is to obtain these services or products with higher quality and lower prices. In order to prioritize customer demand within a favorable competitive environment, it is necessary to meet these requests of services or products in full, or in other words, it must be perfect. This necessity forced organizations to adopt an understanding of Total Quality Management based production. The most critical factor in this approach is that the structure is based on continuous improvement. The method of improving the products/services is by eliminating faults.

For determining and eliminating the faults of an organization's processes, 6σ , competence analysis, lean production, and many other concepts can be used. Organizations have implemented Quality Management Systems such as ISO 9001 and ISO/TS 16949 (recently IATF 16949) to strengthen product quality, corporate image, and operations. Measurement Systems Analysis (MSA) is one of these essential management system tools. Measurement techniques in quality management are used to identify whether a product meets requested specifications. However, differences, volatile results, or variations might occur due to the inspector or measurement equipment in the measurement system. There is always a chance to reject the correct part (Type 1 Error) or accept the wrong part (Type 2 Error). Organizations have been using Measurement Systems Analysis (MSA) to improve business by eliminating these kinds of errors.

The primary purpose of the Measurement Systems Analysis (MSA) is to determine and remove the total variation between measurement methods. The Measurement Analysis System is implemented as a requirement of the Quality Management Systems and is a means of establishing sustainability within the organization. However, it would be wrong to assume that these data obtained by the measurement instrument and the inspector are also completely fault-free. Thus, statistical calculations, evaluations such as hypothesis testing, point, interval estimation, standard deviation, and other simulations are used (Yeh and friends, 2015). By the 1960s, Zadeh (1965) published the concept of Fuzzy for the first time; unlike other statistical calculations, this concept is used to prevent uncertainties.

In recent years, the use of the fuzzy logic approach in quality control has been an area of interest for researchers: Lee (2001) and Hong (2004) predicted the fuzzy Cpk index. Parchami et al. (2005) identified new process capability indices with two membership functions especially for comparing manufacturing processes with fuzzy specification limits, and uncovered interesting relations among the introduced indices. Parchami and Mashinchi (2007) presented a new method for using middle values. Faraz and Bameni Moghadam (2007) and Golbay and Kahraman (2006) mentioned necessary methods for fuzzy quality control charts. Bokov (2011) presented an empirical method for modelling high-pressure gauges in which pneumatic measurements include measurement deviations from measurement experiments using a valid measurement model. Nasiri and Darestani (2016) reviewed the literature on fuzzy control charts between the years 1990 and 2012 because fuzzy control charts had an important role in their study. Koprivica and Filipovic (2018) aimed to present an effective blurring tool in dealing with different types of uncertainty and the application of natural language to model decision-making in quality management. This article shows how fuzzy logic integration can help plan a particular product.

A number of articles from the last decade on Fuzzy MSA are given in Table 1.

Table 1. Literature Review

Author	Title	Fuzzy Number	Sector
Kazemi et al. (2010)	Developing a Method for Increasing Accuracy and Precision in Measurement System Analysis: A Fuzzy Approach	Triangular	Automotive Parts Industry
Hajipour et al. (2013)	A fuzzy expert system to increase accuracy and precision in measurement system analysis	Triangular	Automotive Parts Industry
Moheb-Alizadeh (2014)	Capability analysis of the variable measurement system with fuzzy data	Triangular	Automotive Parts Industry
Rahmati and Amalnick (2015)	Fuzzy Gauge Capability (C_g and C_{gk}) through Buckley Approach	Triangular	Manufacturing Industry
Yeh et al. (2015)	Using Fuzzy Theory in %GR&R and NDC of Measurement System Analysis	Triangular	Machine Tool Factory
Wang et al. (2018)	VLSI Circuit Measurement System Analysis based on Random Fuzzy Variables	Triangular and Trapezoidal	Test boards and Test Programs
Mittal et al. (2018)	On the fuzzy evaluation of measurement system analysis in a manufacturing and process industry environment: A comparative study	Trapezoidal	Manufacturing Industry
Darestani et al. (2021)	Developing Fuzzy Tool Capability Measurement System Analysis	Triangular and Trapezoidal	Automotive Parts Industry

Fuzzy Measurement Systems Analysis (FMSA) is mentioned in response to the uncertainty of the common Measurement Systems Analysis (MSA) method in this study. Thus, the method is focused on getting more precise results. Moreover, since fuzzy indices provide an expanded area for decision-makers, it is thought to be more accurate to use this method.

Firstly, the traditional (typical) Measurement Systems Analysis (MSA) is described, followed by the Fuzzy Measurement Systems Analysis (FMSA) in detail. The system has been observed that the data gained by Fuzzy Measurement Systems Analysis (FMSA) provides more precise results by comparing the applications of both systems on a selected product by a manufacturer of automotive parts.

2. Traditional Measurement System Analysis (MSA)

Measurement System Analysis (MSA) is a collection of statistical methods for the analysis of measuring system capacity (Smith et al., 2007). Identifying, classifying, and evaluating the quality of measurement actions increases the usefulness, accuracy, and significance of measurements. Montgomery and Runger (1993) proposed the MSA as an efficient approach for better Measurement instruments. MSA's primary objectives are to;

- Describe the components of the measurement error,
- Evaluate the contribution of a measurement error due to the total variance of equipment parameters or process-based.
- Figure out the stability of a metrology tool over time by correlating/comparing multiple metrology tools.

To see the inconsistency/variability within a system, the variances in the measurement systems must first be defined and separated from the process (Göndör and Koczor, 2010). The MSA should be implemented on every process in the system since the risk of a flawed measurement system may lead to the acceptance of wrong products or refusing of good products.

Based on the types of data values, the MSA is separated into two groups: measurable measurement values and non-measurable measurement values. Only measurable measurement values will be mentioned within the study's scope.

It is often assumed that measurements are error-free. The analysis and the results are generally based on this assumption. However, in order to focus on the eligible process variability, the variability from the measurement system shall be specified and separated from process variability. Variability of the measurement system is divided into two main categories;

- 1) Accuracy: The difference between the actual value and the measurement value of parts examined.
- 2) Precision: The variation is seen when a piece is measured repeatedly by the same measuring device.

The sort of possible variations in measurement and the measures of these variations are shown in Figure 1:

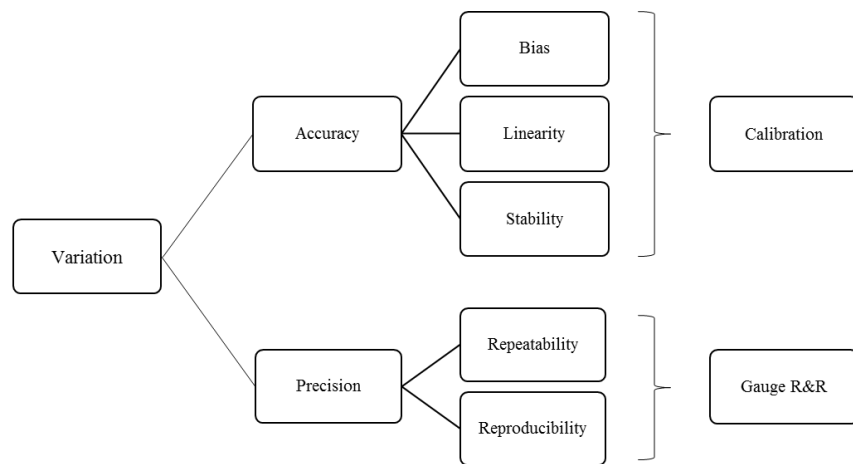


Figure 1. Types of variations (Yeh and Sun, 2013)

2.1. Accuracy

Accuracy is the difference between the measured value and the actual value of the relevant part. The variation can be examined under three categories, as seen in Figure 1:

- 1) Bias: The difference between the observed average of the measurements and the reference value made by sensitive measuring equipment (Ford, 1995).

- 2) Linearity: Linearity is the difference in the measuring device's trend values over the expected operating range (Ford, 2002). Linearity can be determined by selecting parts from the beginning to the end of the measuring device's measuring range.
- 3) Stability: An indication of how accurately the measuring system measures a single characteristic of the same part over time.

2.2. Precision

One of the important purposes of measuring system operation is to gain detailed knowledge of the amount and variability of measurement system's measurement variables interacting with ambient conditions. This information is so valuable that it is far more useful to identify repeatability and trends, and to determine acceptable limits for them, with extremely precise measuring equipment with very high repeatability. Such studies provide the following benefits (Montgomery, 2009):

- 1) Criteria for accepting new measuring equipment.
- 2) Ability to compare one measuring device with another.
- 3) Evaluation of a measuring device that is considered to be inadequate.
- 4) Comparison of the state of the inspector before and after repair.
- 5) Information for calculating the process variability and acceptability level for a production process.

2.2.1. Repeatability

Repeatability is the variability of measurements gained by an inspector when measuring the same characteristic of the same part using a measuring device several times. The repeatability of the measurement process shows the consistency of the measurement system's variance. Measurement differences caused by the measurement tool itself and the use of different measurement tools are the cause of most repeatability errors. Since both of these differences are represented by the subgroup interval (R) of the repeated measures, the interval chart will show the measurement process's consistency.

Measuring device variability or repeatability - Repeated measures and number of inspectors - assuming that the number of products is greater than 15; Repeatability standard deviation (measurement equipment standard deviation, EV);

$$EV = 5.15 \times \frac{\bar{R}}{d_2^*} \tag{1}$$

It is calculated with the formula stated above. "R" is the average change range of the repeated measurements. Where d_2^* equals 1.128.

2.2.2. Reproducibility

Reproducibility is the variability of the averages of the measurements that different inspectors take of the same characteristic of the same part using the same measuring device. The repeatability of the measurement process shows the consistency of the inspector's variance. The variability of the person who performs the measurement shows the increasing tendency that can be attributed to each inspector. If this trend or metric variability is present, the individual aggregate averages of the metrics will be different.

The standard deviation for reproducibility - AV;

$$AV = \sqrt{(5.15 \frac{\bar{X}_{DIFF}}{d_2^*})^2 - \frac{(EV)^2}{n.r}} \tag{2}$$

Here \bar{X}_{DIFF} is found by subtracting the largest inspector average from the lowest inspector average. The number of parts in the equation is n, and r is the number repetition of the measurements for each inspector and for each part.

2.2.3. Gauge R&R

The GR & R analysis is a method used by a system to determine the measurement system's suitability. The total GR & R consists of a variation of the total variation of reproducibility and repeatability:

$$GR\&R = \sqrt{EV^2 + AV^2} \tag{3}$$

The percentage of measurement variation of a GR & R study system is calculated as GR & R% (Golbay and Kahraman, 2006).

There is a slight error in every measurement system in the general literature. So, those error rates are identified as (Montgomery, 2009);

- a) %GR&R ≤ 10 the measuring device is accepted.
- b) %GR&R = 10 to 30 is considered conditional approval.

Currently, the equipment variance (EV) and the measurement variance (AV) are identified according to the conditions of use, and improvements will be made. Conditional approval is given to the measurement equipment that measures critical features, and an action plan is prepared.

- c) % GR & R ≥ 30, the measurement system is developed, the problem is determined, and the fault source is improved. It is desirable that the Number of Distinct Categories (NDC) value gained by dividing the difference, change between the parts by GR & R is at least 5.

$$NDC = 1,14 \times (PV/GR\&R) \tag{4}$$

If the NDC is lower than value "5", the studies include improvements that should be made within the process.

3. Fuzzy Measurement System Analysis (FMSA)

The fuzzy concept was first proposed by Lotfi A. Zadeh, a cybernetic expert at the University of California, Berkeley. The concept was published in an article titled Information and Control (Zadeh, 1965). After being published, it was applied to the systems, and the theory has since become frequently discussed and applied to different approaches in various disciplines. The basis of a fuzzy theory lies in the elimination of uncertainties. It defines ambiguities with quantitative numbers and makes them into workable data. In a fuzzy logic approach that suggests that every piece of information should be expressed intermittently rather than 0 or 1, it is possible to define these intervals with the membership function shown in Figure 2:

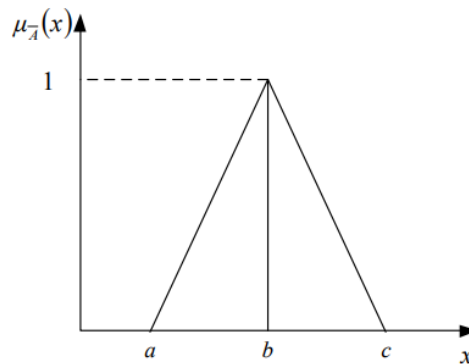


Figure 2. Types of variations (Yeh et al., 2015)

In MSA applications, if the quality level of the measurement system is in a low section, process analysis may not be expected to be valid. For this reason, the fuzzy system MSA is considered to be a far more accurate and reliable method than the conventional one. This precise data analysis will lead to a more accurate decision-making process and quality system.

In FMSA, the steps of the traditional MSA study are applied one by one, and only the figures are given in triple spacing. Here, a value of 0,001 will be applied to the data for fuzzifying the results. (Kahraman and Kaya, 2008):

$$X = (a, b, c) = (b \times \delta_1, b, b \times \delta_2) \quad \delta_1 = 0,999, \delta_2 = 1,001 \tag{5}$$

The steps in the FMSA study can be mentioned as below:

Step 1: n items randomly taken for representing the process are selected and randomly measured by inspectors (raters) and processed in Table 2.

Table 2. Record of measurement outcomes

		PART											
		1	2	3	4	5	6	7			
INSPECTOR / REPEATED													
Ins. A	1. Rep.												
Ins. A	2.Rep.												
...	...												
Ins. B	1. Rep.												
...	...												

Step 2: The received measurement values are fuzzied for gaining triplet range values. It is possible to perform the mathematical operations of the obtained range values as follows (Zadeh 1965):

$$X(a, b, c) \text{ and } Y(d, e, f) \tag{6}$$

$$X + Y = (a, b, c) + (d, e, f) = (a + d, b + e, c + f) \tag{7}$$

$$X - Y = (a, b, c) - (d, e, f) = (a - d, b - e, c - f) \tag{8}$$

$$X \times Y = (a, b, c) \times (d, e, f) = (a \times d, b \times e, c \times f) \tag{9}$$

$$X \div Y = (a, b, c) \div (d, e, f) = (a \div d, b \div e, c \div f) \tag{10}$$

Step 3: The individual averages of the measurements taken for each inspector and their averages are calculated ($X_{a_{ort}}$, $X_{b_{ort}}$, $X_{c_{ort}}$).

Step 4: The range of measurements that each inspector has made and the average of these ranges is calculated ($R_{a_{ort}}$, $R_{b_{ort}}$, $R_{c_{ort}}$).

Step 5: The average of the finally calculated averages ($X_{a_{ort.ort.}}$, $X_{b_{ort.ort.}}$, $X_{c_{ort.ort.}}$) and the average of the intervals are calculated. ($R_{a_{ort.ort.}}$, $R_{b_{ort.ort.}}$, $R_{c_{ort.ort.}}$)

Step 6: The difference between the maximum average and the minimum average is calculated ($X_{a_{DIFF}}$, $X_{b_{DIFF}}$, $X_{c_{DIFF}}$), and the range of each track averages is calculated (R_{a_p} , R_{b_p} , R_{c_p}).

Step 7: The equipment variance (EV) is calculated as:

$$EV = (R_{a_{ort.ort.}}, R_{b_{ort.ort.}}, R_{c_{ort.ort.}}) \times K1 \tag{11}$$

$$EV = (R_{a_{ort.ort.}} \times K1, R_{b_{ort.ort.}} \times K1, R_{c_{ort.ort.}} \times K1) \tag{12}$$

$$EV = (EV_a, EV_b, EV_c) \tag{13}$$

* The K1 value is equal to 5.15 / d2.

Step 8: The inspector variance (AV) is calculated as:

$$\sqrt{(X_{DIFF} \times K2)^2 - \frac{(EV)^2}{n.r}} \tag{14}$$

$$AV = \sqrt{((X_{a_{DIFF}}, X_{b_{DIFF}}, X_{c_{DIFF}}) \times K2)^2 - \frac{(EV_a, EV_b, EV_c)^2}{n.r}} \tag{15}$$

$$AV = (AV_a, AV_b, AV_c) \tag{16}$$

Step 9: As a result, the GR & R value is calculated and interpreted as follows:

$$GR\&R = \sqrt{EV^2 + AV^2} \tag{17}$$

$$GR\&R = \sqrt{(EV_a, EV_b, EV_c)^2 + (AV_a, AV_b, AV_c)^2} \tag{18}$$

$$GR\&R = (GR\&R_a, GR\&R_b, GR\&R_c) \tag{19}$$

4. Case Study and Results

In this study, the data of an automotive parts manufacturer are used. All measuring systems are analyzed per ISO / TS 16949 standards, which are in accordance with the working policy. Since the data obtained in this study were analyzed by the traditional MSA method, the observed values are assumed to be exact. However, with the assumption that these values are not entirely flawless, fuzzy MSA has been used to make clearer and more accurate decisions in this study. As a result of the study, both methods were compared, and the results were evaluated.

In a case study, 10 selected parts were measured by three inspectors (A, B, and C) in three repetitions each; these values are given in Table 3.

Table 3. Record of measurement outcomes

Inspectors / Repetition	PART										
	1	2	3	4	5	6	7	8	9	10	
1. A	1	83,47	83,48	83,47	83,46	83,47	83,46	83,5	83,49	83,51	83,47
2.	2	83,46	83,49	83,47	83,46	83,47	83,46	83,5	83,46	83,51	83,47
3.	3	83,45	83,48	83,47	83,46	83,47	83,47	83,5	83,49	83,51	83,47
4. B	1	83,46	83,49	83,46	83,47	83,46	83,47	83,5	83,49	83,51	83,47
5.	2	83,46	83,46	83,46	83,47	83,46	83,47	83,5	83,49	83,51	83,47
6.	3	83,46	83,49	83,46	83,47	83,47	83,47	83,5	83,46	83,51	83,47
7. C	1	83,46	83,49	83,46	83,46	83,46	83,47	83,5	83,49	83,51	83,47
8.	2	83,45	83,49	83,46	83,44	83,46	83,47	83,5	83,49	83,51	83,47
9.	3	83,46	83,49	83,46	83,46	83,46	83,46	83,5	83,5	83,51	83,47

According to this data, Traditional MSA values are as in Table 4:

Table 4. Traditional MSA results	
Traditional MSA	
% GR&R	22,75
NDC	6,03

According to traditional MSA results, it is possible to say that this measurement system can be accepted after advising with the customer.

To form an ideal measurement system and try to make more precise decisions, the measurement data is fuzzified as in Table 5 and Table 6 with two different fuzzy coefficients:

Table 5. Record of 0,001 fuzzified measurement outcomes

Inspectors / Repetition	PART					
	1	2	3	4	5	
1. A	1	(82,39;83,47;83,55)	(83,40;83,48;83,56)	(83,39;83,47;83,55)	(83,38;83,46;83,54)	(83,39;83,47;83,55)
2.	2	(83,38;83,46;83,54)	(83,41;83,49;83,57)	(83,39;83,47;83,55)	(83,38;83,46;83,54)	(83,39;83,47;83,55)
3.	3	(83,37;83,45;83,53)	(83,40;83,48;83,56)	(83,39;83,47;83,55)	(83,38;83,46;83,54)	(83,39;83,47;83,55)
4. B	1	(83,38;83,46;83,54)	(83,41;83,49;83,57)	(83,38;83,46;83,54)	(83,39;83,47;83,55)	(83,38;83,46;83,54)
5.	2	(83,38;83,46;83,54)	(83,38;83,46;83,54)	(83,38;83,46;83,54)	(83,39;83,47;83,55)	(83,38;83,46;83,54)
6.	3	(83,38;83,46;83,54)	(83,41;83,49;83,57)	(83,38;83,46;83,54)	(83,39;83,47;83,55)	(83,39;83,47;83,55)
7. C	1	(83,38;83,46;83,54)	(83,41;83,49;83,57)	(83,38;83,46;83,54)	(83,38;83,46;83,54)	(83,38;83,46;83,54)
8.	2	(83,37;83,45;83,53)	(83,41;83,49;83,57)	(83,38;83,46;83,54)	(83,36;83,44;83,52)	(83,38;83,46;83,54)
9.	3	(83,38;83,46;83,54)	(83,41;83,49;83,57)	(83,38;83,46;83,54)	(83,38;83,46;83,54)	(83,38;83,46;83,54)
		6	7	8	9	10
1. A	1	(83,38;83,46;83,54)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
2.	2	(83,38;83,46;83,54)	(83,42;83,50;83,58)	(83,38;83,46;83,54)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
3.	3	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
4. B	1	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
5.	2	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
6.	3	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,38;83,46;83,54)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
7. C	1	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
8.	2	(83,39;83,47;83,55)	(83,42;83,50;83,58)	(83,41;83,49;83,57)	(83,43;83,51;83,59)	(83,39;83,47;83,55)
9.	3	(83,38;83,46;83,54)	(83,42;83,50;83,58)	(83,42;83,50;83,58)	(83,43;83,51;83,59)	(83,39;83,47;83,55)

Table 6. Record of 0,01 fuzzified measurement outcomes

Inspectors		PART				
/		1	2	3	4	5
Repetition						
1. A	1	(82,64;83,47;84,30)	(82,65;83,48;84,31)	(82,64;83,47;84,30)	(82,63;83,46;84,29)	(82,64;83,47;84,30)
2.	2	(82,63;83,46;84,29)	(82,66;83,49;84,32)	(82,64;83,47;84,30)	(82,63;83,46;84,29)	(82,64;83,47;84,30)
3.	3	(82,62;83,45;84,28)	(82,65;83,48;84,31)	(82,64;83,47;84,30)	(82,63;83,46;84,29)	(82,64;83,47;84,30)
4. B	1	(82,63;83,46;84,29)	(82,66;83,49;84,32)	(82,63;83,46;84,29)	(82,64;83,47;84,30)	(82,63;83,46;84,29)
5.	2	(82,63;83,46;84,29)	(82,63;83,46;84,29)	(82,63;83,46;84,29)	(82,64;83,47;84,30)	(82,63;83,46;84,29)
6.	3	(82,63;83,46;84,29)	(82,66;83,49;84,32)	(82,63;83,46;84,29)	(82,64;83,47;84,30)	(82,64;83,47;84,30)
7. C	1	(82,63;83,46;84,29)	(82,66;83,49;84,32)	(82,63;83,46;84,29)	(82,63;83,46;84,29)	(82,63;83,46;84,29)
8.	2	(82,62;83,45;84,28)	(82,66;83,49;84,32)	(82,63;83,46;84,29)	(82,61;83,44;84,27)	(82,63;83,46;84,29)
9.	3	(82,63;83,46;84,29)	(82,66;83,49;84,32)	(82,63;83,46;84,29)	(82,63;83,46;84,29)	(82,63;83,46;84,29)
		6	7	8	9	10
1. A	1	(82,63;83,46;84,29)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
2.	2	(82,63;83,46;84,29)	(82,67;83,50;84,34)	(82,63;83,46;84,29)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
3.	3	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
4. B	1	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
5.	2	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
6.	3	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,63;83,46;84,29)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
7. C	1	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
8.	2	(82,64;83,47;84,30)	(82,67;83,50;84,34)	(82,66;83,49;84,32)	(82,67;83,51;84,35)	(82,64;83,47;84,30)
9.	3	(82,63;83,46;84,29)	(82,67;83,50;84,34)	(82,67;83,50;84,34)	(82,67;83,51;84,35)	(82,64;83,47;84,30)

According to the fuzzified values, the fuzzy MSA values resulting from the calculations are as follows; for 0,001 coefficient %GR&R 23,73 and NDC 5,77. For 0,01 coefficient %GR&R 22,75 and NDC 6,03. According to fuzzy MSA results, it is possible to say that this measurement system can be accepted after advising with the customer.

The results of both the fuzzy and the traditional method are shown in table 7:

	Traditional MSA	Fuzzy MSA (0,001)	Fuzzy MSA (0,01)
% GR&R	22,75	23,73	22,75
NDC	6,03	5,77	6,03

It can be seen from the results that the analysis of measurement systems made with fuzzy values are closer to the probable rejection of the system. This means that the fuzzy MSA method should be preferred to eliminate a type 1 error. It is observed that in the analyzes made with fuzzy data, values are given intermittent values, hence giving more accurate results. As the fuzzified coefficient increases, the deviations in the right and left values are high, and the results seem to approximate the traditional methods.

5. Conclusion

In today's competitive conditions, trying to progress only with technological studies does not bring them success. Effective strategy choices, especially in the field of engineering, play an important role in achieving success. Elimination of uncertainties is an important issue in creating an effective strategy. Many studies have been done to eliminate the uncertainty environment in the processes, and fuzzy logic studies are one of the most popular in the field of engineering today.

Measuring systems traditionally use precise data. However, there may be cases where the user cannot always find the exact data. The way to account for such uncertainties in a measurement system is to work with imprecise data. Thus, it is possible to turn uncertainty into opportunity. In this study, the commonly used Measurement System Analyze (MSA) statistical tool was used to analyze measurement systems. An ideal measurement system should provide zero error in the measured value; however, there is no such system. For this reason, managers choose the MSA method with statistical properties. Traditionally MSA studies have included precisely observed values, which are not entirely flawless. The fuzzy MSA method is included in the study as an alternative method to these uncertain values. The exact values of the product of an automotive parts manufacturer were transformed into fuzzified values by the fuzzified coefficient, so the results became more realistic.

Since there is not much literature in the field of fuzzy MSA study, it will be a pioneer for new research. Future studies may include different methods of fuzzification. Furthermore, fuzzy values can be weighted according to inspectors to create a different study.

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