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DEVELOPMENT POSSIBILITY OF PROCESS AUDIT EVALUATION BASED ON VDA 6.3 STANDARD BY FUZZY LOGIC APPLICATION

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ABSTRACT

Gemany has a keyrole in the automotive industry of the World. Due to this, the standards created and managed by VDA (Verband der Automobilindustrie) are determinative for all the german based OEM (Original Equipment Manufacturer) and their complete supply chain. VDA standards are created with attendance such as companies, like Audi, Continental, Daimler, Porsche, Knorr-Bremse, Robert Bosch, Volkswagen, or ZF Sachs. The Tier 1 suppliers of OEM are the system suppliers (for example breaking system, turbo system) have to guarantee, that the sub-suppliers (Tier 2, Tier 3, etc.), who produce components (like bearing, turbine housing) are respect the ISO/TS 16949 standard and also for the OEM specific requirements. The authors have examined the recommendation of VDA 6.3 German automotive standard for the evaluation of the serial process audit in an earlier study. In this paper we examine a possible alternative evaluation based on fuzzy logic and the potential advantages will be presented via an example. A fuzzy logic based calculation method is presented, which can offer an evaluation to model the human thinking. Considering, that the whole evaluation system is based on experts`opinion, it can give a more precise and adequate results.

Keyword: VDA 6.3, ISO/TS 16949, fuzzy mathematics, serial process audit evaluation

1. INTRODUCTION

The rule of Germany in the automotive industries of the World is undoubted, due to this the standards published by German Automotive Association, VDA (**V**erband **d**er **A**utomobilindustrie) are determinative for all the German based automotive companies and the complete supply chains. The VDA standard [15] were prepared with the cooperation of companies like Audi, Continental, Daimler, Porsche, Knorr-Bremse, Robert Bosch, Volkswagen and ZF Sach. The Tier 1 suppliers have to guarantee, that the components from sub-suppliers (Tier 2, Tier 3, etc.) conform to the ISO/TS 16949 and the OEM (Original Equipment Manufacturer like Audi, Daimler) standards.

The authors' earlier results in supplier evaluation are in [9, 10, 13, 14] but Krause, Humphreys and Esse investigated the supplier evaluation with different method in [1, 2, 4]. One can take [11, 12] to get indroduction into fuzzy mathematics. A literature review can be found about fuzzy risk assessment in [5] and for instance some further applications in [6, 7, 8]. Fuzzy inference systems is investigated by Johanyák in [3] where it was tuned up with the application of the clonal selection algorithm and two different types of initialization was made for SISO and MISO systems.

The aim of this paper is to have a more comprehensive picture about the usage and the efficiency of this method.

The outline of the paper is as follows: The Section 2. presents the evolution of the management systems. The Section 3. the autors will review the proposed calculation

way for the VDA 6.3 process audit results evaluation. In Section 4., the authors define the research plan for the future. Section 5 presents the references.

2. EVALUATION OF SERIAL PROCESS AUDIT RESULTS

The audit during the audit examine areas like project management, planning the product and process development, carrying out the product and process development, supplier management, process analysis/production and customer satisfaction. The examined areas are shown at Table 1.

Examined area	
Project management (P2)	E_{PM}
Planning the product and process development (P3)	E_{PP}
Carrying out the product and process development (P4)	E_{PR}
Supplier management (P5)	E_{LM}
Process analysis / production (P6)	E_{PG}
Customer support / customer satisfaction / services (P7)	E_K

Table 1. Examined areas (source: [15])

VDA provide recommendation for the audit with concrete questions, potential areas to examine, tools, documentations, affected areas with oriented questions are refer to other relevant standards.

These questions can be completed with further questions, so a questionnaire will be provided what can be followed by the auditor and all answers can be evaluated with 0-4-6-8-10 points. The evaluation system is presented in Table 2.

Point	**Assessment of compliance with the requirements**
10	Full compliance with requirements
8	Requirements mainly satisfied, minor deviations
6	Requirements partially satisfied, significant deviations
4	Requirements inadequately satisfied, major deviations
0	Requirements not satisfied

Table 2. Evaluation of the answers (Source[15])

Classification	Overall level of achievement E_G [%]	Description of the classification
A	$E_G >= 90$	Quality-capable
B	$80 =< E_G < 90$	Conditionally quality-capable
C	$E_{G<80}$	Non quality-capable

Table 3. Classification of performance (source: [15])

Area	Question	X. auditor evaluation	Y. auditor evaluation	Z. auditor evaluation
LM	1	8	8	6
	2	8	6	8
	3	8	6	8
	4	10	8	6
	5	10	10	6
	Total Sum	44	38	34
	Percent %	88	76	68
PG	1	10	10	8
	2	8	8	10
	3	8	8	8
	4	6	6	6
	5	8	8	6
	6	10	6	10
	7	10	8	8
	Total Sum	60	54	56
	Percent %	85.7	77	80

Table 4. The baseline data

Minimum 2/3 of the questions have to be evaluated to have a valid audit. The principle of the evaluation is shown by equation (1).

$$E_E[\%] = 100\frac{TNPARQ}{TPPARQ}, \tag{1}$$

where:

$TNPARQ$ – Total Number of Points Awarded for Relevant Questions,

$TPPARQ$ – Total Possible Points Awarded for Relevant Questions.

During the calculation we compare the awarded points per areas with the total possible awarded points. One of the most important milestones in the lifetime of a product is the SOP (Start of Production)

The standard defines the level of achievement before SOP (E_D):

$$E_D[\%] = \frac{E_{PM} + E_{PP} + E_{PR}}{3} \tag{2}$$

and the level of achievement after SOP (E_P):

$$E_P[\%] = \frac{E_{LM} + E_{PG} + E_K}{3}. \tag{3}$$

The performance is regarding the relevant time period and the total performance is:

$$E_G[\%] = \frac{E_{PM} + E_{PP} + E_{PR} + E_{LM} + E_{PG} + E_K}{6}, \tag{4}$$

where explanation are in Table 1.

The supplier got a classification after the summary, please see in Table 3. Finally the supplier got a classification regarding the evaluation of the process belongs to the relevant project. This can be A, which means the supplier is suitable for further mutual work, fulfill the requirements. B rank means, serious problems were pointed out during the audit; due to this the supplier has to do the requested actions to eliminate the issues. This audit has to be followed by a re-audit to verify the implemented actions. The worst class is C level, which means serious issues and risks were found during the audit, the supplier not fulfill the requirements, the mutual work is not suggested.

3. DEFINITION OF SAMPLE MODEL

The audit is normally done with the participation of more auditors. The sample below shows a case with three auditors and they have to evaluate two areas with five and seven questions. Please see the data in Table 4.

3.1 Sample modell evaluation with VDA method

Using the data from Table 4 to the equation 1, we will get the results below in case of auditor X:

$$E_{LM\_X}[\%] = 100\frac{8+8+8+10+10}{10+10+10+10+10} = \frac{44}{50} = 88\%, \tag{5}$$

$$E_{PG\_X}[\%] = 100\frac{10+8+8+6+8+10+10}{10+10+10+10+10+10+10} = \frac{60}{70} = 85.7\%. \tag{6}$$

Based on the VDA we need to average partial results for X, Y and Z auditors:

$$E_{E\_X}[\%] = \frac{88+85.7}{2} = 86.85\%, \quad E_{E\_Y}[\%] = \frac{76+77}{2} = 76.5\%, \quad E_{E\_Z}[\%] = \frac{68+80}{2} = 74\% \tag{7}$$

Summary:

$$E_G[\%] = \frac{86.85+68.5+74}{3} = 76.45\%. \tag{8}$$

The result is 76.45%, so the supplier got C class, non quality-capable.

3.2 Sample model evaluation with fuzzy based method

The authors provide another method in this section illustrated by a sample which based on fuzzy mathematics. All structure of the VDA is based on human thinking and all groups which are created are containing uncertainties because they use notions. To have description for these notions, fuzzy mathematics is used because fuzzy can

handle the uncertainties of notions as linguistic variables. Also in Table 3, there are 3 groups.

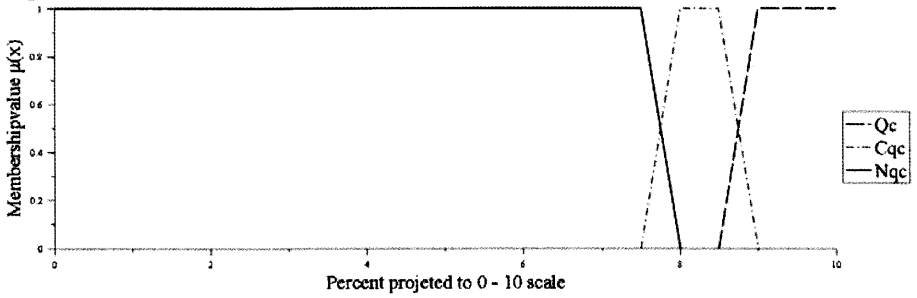

Figure 2. Fuzzy membership functions for VDA evaluation

The linguistic variable is the classification and its values are the next: **Q**uality-, **C**onditionally **q**uality-, and **N**on **q**uality-**c**apable; short sign for them are in order Qc, Cqc and Nqc. All of these can be seen in Figure 2. which represent their fuzzy membership functions. The baseline data are in Table 4. to use for the fuzzy model. Each opinion – in percent – is fuzzyfied and gets the fuzzyfied form which results are in Table 5. where μ(x) is the fuzzy membership value. Now the fuzzyfied form are used for have one common LM opinion and PG opinion in percent and of course it is possible to have the X', Y's and Z's opinions in percent furthermore to have the final crisp value for evaluation. To defuzzyfy, authors use the **c**enter **o**f **g**ravity (COG) method. The calculation was made with Maple.

		LM				PG			
	Classifi-cation	μ(x)	Center of gravity x_w	Area G	$x_w \cdot G$	μ(x)	Center of gravity x_w	Area G	$x_w \cdot G$
X	Qc	0.6	9.325	0.81	7.553	0.14	9.267	0.2051	1.901
	Cqc	0.4	8.25	0.52	4.29	0.86	8.249	0.9202	7.591
	Nqc	0	0	0	0	0	0	0	0
Y	Qc	0	0	0	0	0	0	0	0
	Cqc	0.2	8.25	0.28	2.31	0.4	8.25	0.52	4.29
	Nqc	0.8	3.9	6.24	24.34	0.6	3.925	4.71	18.49
Z	Qc	0	0	0	0	0	0	0	0
	Cqc	0	0	0	0	1	8.25	1	8.25
	Nqc	1	3.875	7.75	30.03	0	0	0	0

Table 5. Partial results for fuzzy based VDA evaluation method

To calculate the common LM opinion one should add the elements of column "$x_w \cdot G$" which belongs to column LM so this will the nominator. To have the denominator one should add the elements of column of "area G" which belongs to column LM (see in Table 5.) and now one get the common LM opinion if one divides the nominator by denominator. So the common opinion about LM is 4.392 also in percent 43.92% (see Figure 3.). To have the opinion about PG is same but one should take into consider that columns PG are used for calculation (Table 5.). So the common

opinion about PG is 5.509 also in percent 55.09% (see Figure 4.). To summarize the results one should add all elements of columns "x_w·G" and divides by adding all elements of columns "area G". So the summary result is with fuzzy based evaluation method $E_G = 47.47\%$. This result is taken into consider by Table 3. So, one should reject this supplier because its result belongs to non quality-capable group.

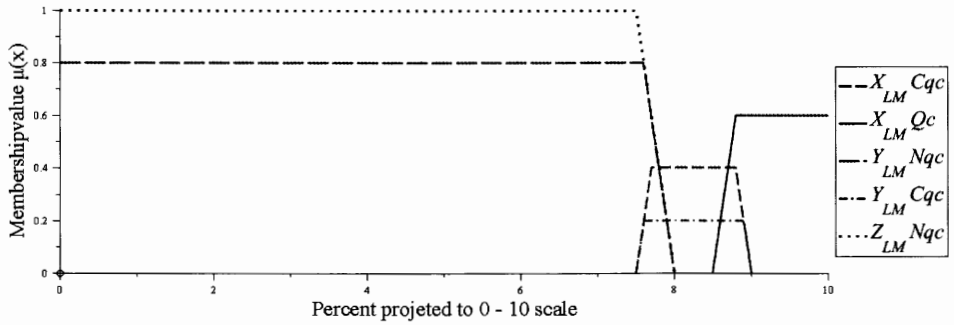

Figure 3. The common fuzzy opinion about LM.

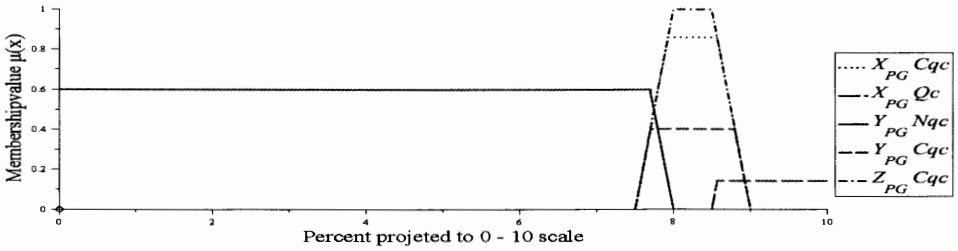

Figure 4. The common fuzzy opinion about PG

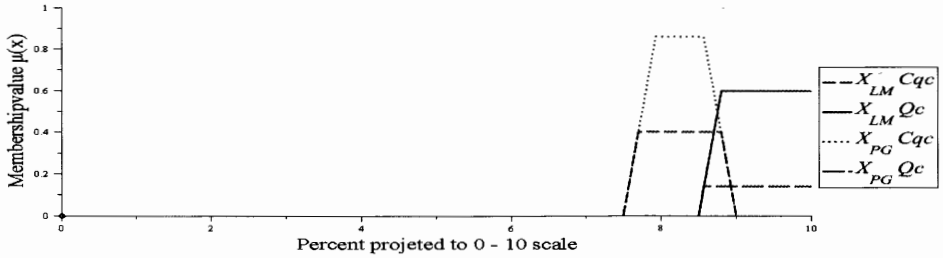

Figure 5. X' fuzzy opinion about supplier and its crisp value is 86.88%.

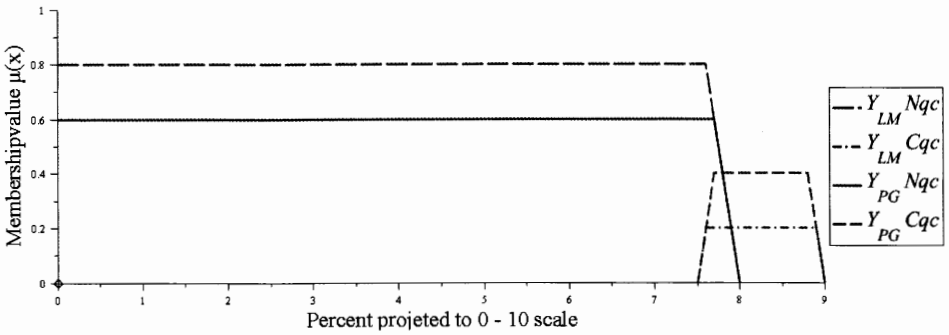

Figure 6. Y's fuzzy opinion about supplier and its crisp value is 42.07%.

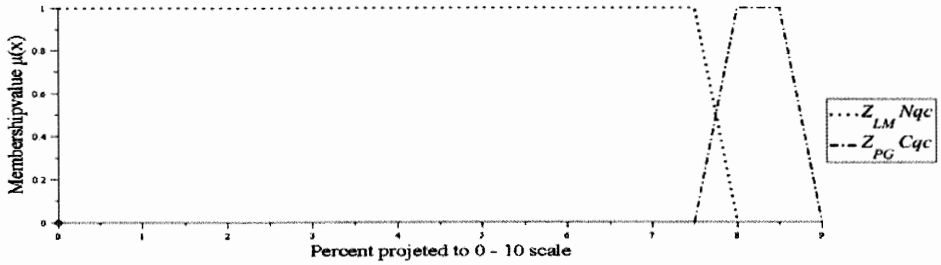

Figure 7. Z's fuzzy opinion about supplier and its crisp value is 43.75%.

4. SUMMARY

The authors investigated the possibility of use of fuzzy mathematics at VDA evaluation. The authors' opinion is that fuzzy mathematics can be used because of notions are used for thinking. Therefore it always contains uncertainties which can be described with fuzzy mathematics. In this case fuzzy method shows if a supplier has a weakness then this method punish with lower points in percent so it can be daresay that the fuzzy based method is much stricter then the classic one. So the suppliers are interested to develop their quality of products.

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