ANNALS OF MTeM FOR 2011 &

PROCEEDINGS

OF THE 10TH INTERNATIONAL CONFERENCE
MODERN TECHNOLOGIES IN MANUFACTURING
6th-8th OCTOBER 2011

EDITOR: Cs. Gyenge
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Descrierea CIP a Bibliotecii Nationale a Romaniei
INTERNATIONAL CONFERENCE MTeM
Proceeding of the 10th International Conference MTeM,
Cluj-Napoca, 6th – 8th October 2011
Ed:Cs.Gyenge – Cluj – Napoca:
p. 335; cm 21/29,7
Bibliogr.
Index.
ISBN 978-606-8372-02-0
Editura Mures

Tiparul executat la S.C. CROMATIC TIPO S.R.L.
Targa Mures, str. Calarasilor nr. 58
Tel./fax: 0265-215597
E-mail: cromatictipo@cromatictipo.ro
Web site: www.cromatictipo.ro

Additional copies can be obtained from the publisher:
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DEVELOPMENT OF SUPPLIER-RATING
BASED ON FUZZY SET THEORY

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Abstract: During inspections the product of the supplier has to be rated according its quality, this is called supplier-rating, which uses sharp crisp boundaries. Abuse could be received by suppliers when they try to stay up or down – depend on pointing system – near these boundaries therefore the authors have made a new method to make the supplier-rating continuously and to have a more correct inspection system of course in viewpoint of manufacturing.

Key words: Supplier evaluation, fuzzy set theory, quality management, set transition.

1. INTRODUCTION

In manufacturing industries there are buying and supplier firms. We will precede our examinations from perspective of buying firms. Customer satisfaction is really important for every company and product quality has key role in it. The product quality is basically determined by raw material quality, so the success of buyer firms, quality of the products is mainly influenced by suppliers! That is why continuous supplier monitoring, evaluation and implement actions immediately in case of weak performance, means the basis of supplier quality assurance.

Esse, Humphreys, Krause and Ellram have studied the supply chain and the quality of product(s) of the suppliers with lot of results and some of these are used in this study (Esse 2008); (Humphreys et al. 2007); (Krause et al., 1997). Furthermore Ross and Retter have studied fuzzy set- and fuzzy logic theories and some of their methods from fuzzy set theory have been used in this study (Retter 2006); (Ross 2010).

The goal of this paper is to introduce the classic calculation method based on failure rate which widely used in industry. We will examine the weak point of this method and suggest possible solution to eliminate this bottleneck.

The paper will be organized as follows: Section 1 shows the applied literatures and the main goals of investigation. Section 2 introduces the classic method of supplier rating. Section 3 shows the constant set transition with line trapeze legs fuzzy membership functions based on fuzzy set theory. Section 4 words proportional set transition with line trapeze legs fuzzy membership functions based on fuzzy set theory too. Section 5 presents application of methods and its results Section 6 shows conclusions and future work.

2. CLASSIC METHOD

2.1 Calculation

The classic calculation will be introduced in this chapter.

The complete evaluation contains many important areas like quality, supply chain, costs, customer service. We will precede our examinations from quality side; examine the failure rate based quality evaluation.

A standard number should be introduced, which will show the basic data of the calculation. It is DPPM (Defected Parts Per Million) number, shows the rate of failed and received parts.

The rate should be multiplied by one million to get a number which easy to compare in case of different suppliers and quarters.

$$\text{DPPM} = \frac{\text{NWCE}}{\text{NACEFS}} \times 1000000$$

where:

NWCE – Number of Wrong Constructional Elements,
NACEFS – Number of All Constructional Elements From Supplier.
The next step is to check the point value of the calculated DPPM number in a chart defined by quality assurance experts. This chart is shown on table 1.

The received and failed quantity is necessary for a supplier in a quarter to do the calculation. These values are defined by the authors below:

- Received quantity: 1 000 000 pcs
- Non-conforming quantity: 2 001 db
- Based on equation (1) the DPPM number is: 2 001 DPPM

From table 1, we can see, the supplier gets 17 points out of 20. It means it lost 3 points out of 20, this is 15% difference. What would be happened, if the non-conforming quantity would be less with one, but the received quantity would be the same? In that case:

- Received quantity: 1 000 000 pcs
- Non-conforming quantity: 2 000 pcs
- a DPPM number: 2 000 DPPM

Now the supplier reached 20 points out of 20 in spite of it got 1 point less out of one million. The point value would be maximal 20 points as well in case of 1 DPPM.

### Table 1. Groups based on DPPM

<table>
<thead>
<tr>
<th>Metal-Supplier</th>
<th>DPPM</th>
<th>%</th>
<th>Rating point (mark)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 2000</td>
<td>0.20 %</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>2001 - 4000</td>
<td>0.40 %</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>4001 - 7500</td>
<td>0.75 %</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>7501 - 10000</td>
<td>1.00 %</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10000 - 15000</td>
<td>1.15 %</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>&gt; 15000</td>
<td>&gt; 1.15 %</td>
<td>0</td>
</tr>
</tbody>
</table>

### 2.2 Problem of this method

The difference between 2 000 – 2 001 DPPM is 0.0001 %, but it cause 15 % difference in the points, while the difference between 1 and 2 000 DPPM is 2 000 times higher than in the previous case, but it not caused any difference it the points!

The feature of hard mathematics caused this effect, because crisp boundaries were used to make categories for the final points. This is shown on Fig. 1.

More lines could be implemented in table 1., but it would not solve the issue, just decrease the differences and increase the administrative resource demand. The authors’ opinion that the solution can be developed based on fuzzy set theory. This combination would be able to establish a modulated supplier evaluation which is much more similar to the common thinking. The graphical illustration of this combination would be similar like on Fig. 1, but the connection between DPPM number and point value would be a continuous curve instead of finite lines. We are spire to achieve it in the chapters below.

![Fig. 1. Basic case: the curve of rating point–DPPM](image)

### 3. CONSTANT SET TRANSITION WITH LINE TRAPEZE LEGS

In this chapter the solution of our problem will be discussed which based on fuzzy set theory. Set transition is called as the length of projection of trapeze legs to the abscissa. It is signed with $H$.

What kind of result is provided if constant set transition is taken, which means all groups have the same constant. Experts should define this constant according to their experiences. In our examination the next constant set transition numbers was chosen: 400 and 2000 DPPM, to investigate the changing of the curve of rating point – DPPM. The computation method:

$$M = \frac{\sum_{i=1}^{n} P_i \times \mu_i(DP)}{\sum_{i=1}^{n} \mu_i(DP)} ,$$  \hspace{1cm} (1)$$

where:
- $DP$ – DPPM number
- $M$ – rating point which belongs to the given $DP$,
- $P_i$ – mark which belongs to the $i^{th}$ fuzzy membership function,
- $\mu_i(DP)$ – the value of the $i^{th}$ fuzzy membership function.
function to given DP,

\[ n \] – the number of fuzzy membership functions.

**4. PROPORTIONAL (OR RATE) SET TRANSITION WITH LINE TRAPEZE LEGS**

In this case the set transition is proportional with the set-size. The set transition is given according to percentage point of set-size.

In our examination the next percentage was chosen 10 and 25% to investigate the changing of the curve of the rating point – DPPM. The computation method uses equation (2), but the fuzzy membership functions are different from previous chapter.

This computation method is a progress against to the basic case, because continuous transition is provided on the limit of sets and the rating point has a rate changing according to the DPPM. If the set transition is increased then the changing will be uniform.

By value of 2000 DPPM set transition it is considerable that the 17 point set is disappearing, and the others still remain Pl. see Fig.2. That shows a weak point, if constant set transition is used then different size of sets cause different changing by different sets which are not proportional with set-sizes.

The next step is to examine when the set transition is chosen proportional with set-size.

**5. APPLICATION OF METHODS**

The evaluated rating point of 7500, 7501 and 7510 DPPM is showed on table 2. In case of 7500 DPPM 15 point is provided with classical method. In other two cases 12.5 point is
evaluated.

In case of 7501 DPPM the supplier gets less than 33.33 % by classical method despite of increasing of failure part was only one piece from one million parts.

The result of the calculation of 7501 DPPM was 12.488 rating point with constant set transition by 400 DPPM, from this the rate of change was 0.096 % compared to 12.5 rating point despite of 33.33 % when the DPPM changed “just” with 0.0001 %. To have this calculation for 7510 DPPM, the rate of change is 0.01 %. The Authors would like to achieve this goal. It is considerable if the set transition is increased then the result will be more precise. In case of 2000 DPPM the changing was already 0.016 % for 7501 DPPM and 0.21 % for 7510 DPPM in rating point.

If the DPPM is increased away up to 7510, the classical method presents 10 points despite of the rate of the change is 10 times like in the last case (from 7500 to 7501 DPPM) which inducts 33.33 % the change of the rating point.

Table 2. Results of applications of methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>7500 DPPM</th>
<th>7501 DPPM</th>
<th>7510 DPPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic</td>
<td>15</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Constant set transition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H=400 DPPM</td>
<td>12.5</td>
<td>12.488</td>
<td>12.375</td>
</tr>
<tr>
<td>H=2000 DPPM</td>
<td>12.5</td>
<td>12.498</td>
<td>12.475</td>
</tr>
<tr>
<td>Proportional set transition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H=10 % DPPM</td>
<td>12.5</td>
<td>12.492</td>
<td>12.415</td>
</tr>
<tr>
<td>H=25 % DPPM</td>
<td>12.5</td>
<td>12.496</td>
<td>12.465</td>
</tr>
</tbody>
</table>

For proportional set transition the previous calculation is be able to do, the results will be a little bit different from the previous rates. The Authors’ opinion is that the proportional set transition provides better rating point because of that method considers set-sizes. Therefore it gives back better the human thinking because of wrong results is calculated if constant set transition is used because set-sizes are different in practice. Therefore the Authors suggest using the proportional set transition in practice. Set-sizes, set transitions and the rate of set transitions should be chosen and this decision always should be done by quality managers and experts of the given manufacture according to industry-specific requirements and their experiences. This developed procedure requires further adjustment.

On the curve of the rating point–DPPM it is considerable that the transient phases, expect the constant phases, are somewhere convex somewhere else concave and that is not allowed because it means between groups different rating point method.

6. CONCLUSION

It is right base for evaluation of suppliers based on fuzzy set theory to develop a correct supplier-rating system. This study identifies, that raised by Authors, is able to use. This method has the next results: first the sharp crisp boundaries have been eliminated; on the other hand the different set-sizes have been taken into consideration by evaluation. The Authors down that the method should be developed further more. The subject of the further examination is to eliminate the problem of convexity on the transition of rating point–DPPM curve.

REFERENCES