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Development of fuzzy supplier-rating by trapeze fuzzy membership functions with trigonometrical legs

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Abstract

In every fields of industry, suppliers create the elements for the final products of OEM (Original Equipment Manufacturer), which means, suppliers ”define” the quality of the final products via the quality of elements. Due to this, the continuous evaluation of supplier performance can be one of the most efficient risk assessment tools to identify weakness in early stages, make the possibility to implement corrective actions in time. The paper offers new development of supplier-rating based on fuzzy set theory where trapeze fuzzy membership functions are used with trigonometrical legs. This investigation is made for providing better rating by the authors. This interpretation is more effective and correct of course in point of view of manufacturing.

Keywords: Supplier evaluation, fuzzy set theory, quality management, set-transition.
2000 MSC: 03E72, 03E75.

1. Introduction

In industrial field there are two types of companies. One of them is OEM (Original Equipment Manufacturer) and the other ones are suppliers. The continuous evaluation of supplier performance should be one of the most efficient risk assessment tools to identify weakness in early stages, make the possibility to implement corrective actions in time. One of the authors is a practical expert, who provided this problem. The practical experts always think with notions and the transitions between the notions is described well with fuzzy mathematics. In manufacturing it is indispensable to rate the suppliers because the quality of the product(s) mainly depends on supplier according to (Esse, 2008),(Humphreys *et al.*, 2007) and (Krause & Ellram, 1997). They have been studied the supply chain and what kind of condition should be to have high quality of product(s). The authors have been studied the supplier rating in their earlier papers like (Portik *et al.*, 2011) and achieved some results which will be shown in section two. To have base for fuzzy set theory and logic it is a good introduction (Ross, 2010) and (Retter, 2006).

Liu, Martínez, Wang, Rodríguez and Novozhilov made a very deep overview about application of fuzzy mathematic which cover wide range of fields of applications to show possible utilizations of risk assessment activities, which were created to identify risk, what could be potential source of harm, or reason of quality

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problems. Risk assessment is the most efficient tool to sufficiently minimize the relevant risk in whole life cycle stages including design, implementation and operation (Liu *et al.*, 2010). Even in military science it can be used fuzzy logic for risk assessment according to (Pokorádi, 2002). Pokorádi gives complex description of methods applied for fuzzy logic based decision making (Pokorádi, 2008). Another Pokorádi's paper used fuzzy logic to model inaccuracy and uncertainty of human thinking and proposed fuzzy logic application for risk assessment of hazards connected with hydraulic system (Pokorádi, 2009).

The ”classical” way of supplier evaluation is to create groups with crisp boundaries based on measurement values like DPPM (Defect Part Per Million). The main disadvantage of crisp boundaries, that small difference in the input can cause big difference in the output.

The aim of this paper is to present this issue and show a new method in supplier rating which is better rating on transient phases. It has been stated that evaluated model can be used by the practicing engineers who do not have knowledge and expert on fuzzy mathematics.

The outline of the paper is as follows: The Section 2. shows authors' earlier results and a proof that the classical trapeze fuzzy membership functions are not good for rating on transient phases. what it means a fuzzy membership function with trigonometrical legs. The Section 3., what it means a fuzzy membership function with trigonometrical legs, explains the constant set-transition in rating-points similarly presents the proportional set-transition as well. The Section 4. provides the application of the constant and the rate set-transition. The Section 5. gives the conclusion and future work.

2. Earlier results

In this introduction the authors present some earlier results which was achieved in some earlier papers. This examination is based in point of view of the failure rate evaluation. It should be introduced a standard number in equation (2.1) which is called DPPM (**D**efected **P**arts **P**er **M**illion).

Definition 2.1. DPPM number is defined with the following equation:

$$DPPM = \frac{NNCE}{NAEFS} \times 1000000, \tag{2.1}$$

where:

NNCE – **N**umber of **N**on-**C**onform **E**lements,
NAEFS – **N**umber of **A**ll **E**lements **F**rom **S**upplier (Portik *et al.*, 2011).

On DPPM numbers are created some groups which is shown on Table 1. This groups have crisp boundaries which should be fuzzyfied to make more sensible rating for suppliers. Our fuzzy mathematic based on (Ross, 2010) and (Retter, 2006). Our problem is graphically represented on Fig. 1 and Fig. 2.

Table 1
Groups based on DPPM

DPPM	%	Rating-Point (*mark*)
0—2000	0.2 %	20
2001—4000	0.4 %	17
4001—7500	0.75 %	15
7501—10000	1.00 %	10
10001—15000	1.15 %	5
> 1500	≥ 1.5 %	0

For further investigation the authors introduced so-called *set-transition*.

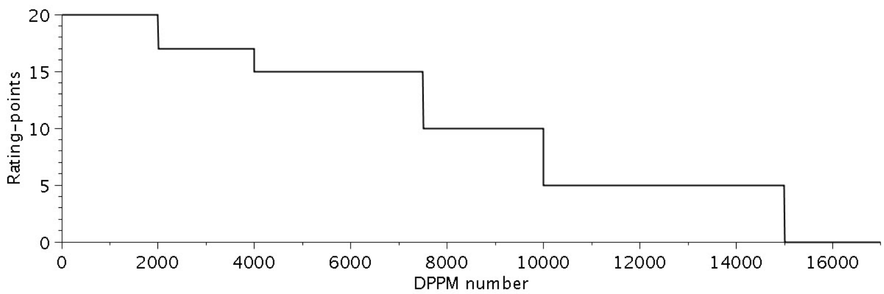

Figure 1. The graphical representation of the basic problem.

Definition 2.2. *Set-transition* is called as the length of projection of trapeze legs to the abscissa. It is signed with H (Portik *et al.*, 2011).

By definition of set-transition, it was investigated with line trapeze-legs fuzzy membership functions if the H was constant or proportional. In case of H is constant, the set-size is not to take into consider. If H is rate then the set-size is taken into consideration. The problem was that the transient phases come somewhere concave somewhere else convex and this is not allowed because it takes different methods between the rating transient phases e.g. it is shown on Fig. 3 and Fig. 4. The calculation method was the next:

$$M = \frac{\sum_{i=1}^{n} P_i \times \mu_i(DP)}{\sum_{i=1}^{n} \mu_i(DP)} \tag{2.2}$$

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 to given DP,
n	–	the number of fuzzy membership functions (Portik *et al.*, 2011).

A classical trapeze fuzzy membership function is given by equation (2.3) and the short sign for it is $\mu(x)_{classic} = [a,b,c,d]_{classic}$.

$$\mu(x)_{classic} = \begin{cases} \frac{x-a}{b-a} & ; \quad a \le x < b \\ 1 & ; \quad b \le x \le c \\ \frac{d-x}{d-c} & ; \quad c < x \le d \\ 0 & ; \quad \text{otherwise} \end{cases} \tag{2.3}$$

This was a short overview about earlier results.

Proposition 1. *There exist such transient phases by classical trapeze fuzzy membership functions which are given by proportional set transition, that some of them are convex and the other ones are concave and the computation is made by two trapeze legs only.*

Proof. The formulation is for proving it is the next according to equation (2.2):

$$M(x)_{i,i+1} = \frac{[a_i,b_i,c_i,d_i]_{classic} \cdot p_i + [a_{i+1},b_{i+1},c_{i+1},d_{i+1}]_{classic} \cdot p_{i+1}}{[a_i,b_i,c_i,d_i]_{classic} + [a_{i+1},b_{i+1},c_{i+1},d_{i+1}]_{classic}} = \frac{\frac{d_i-x}{d_i-c_i} \cdot p_i + \frac{x-a_{i+1}}{b_{i+1}-a_{i+1}} \cdot p_{i+1}}{\frac{d_i-x}{d_i-c_i} + \frac{x-a_{i+1}}{b_{i+1}-a_{i+1}}} =$$

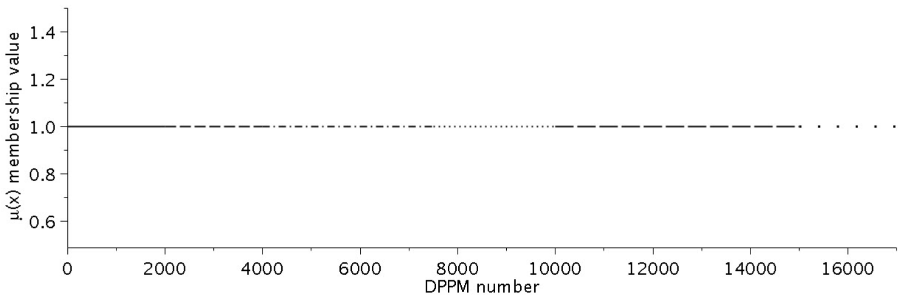

Figure 2. The fuzzy membership functions which belong to the basic problem.

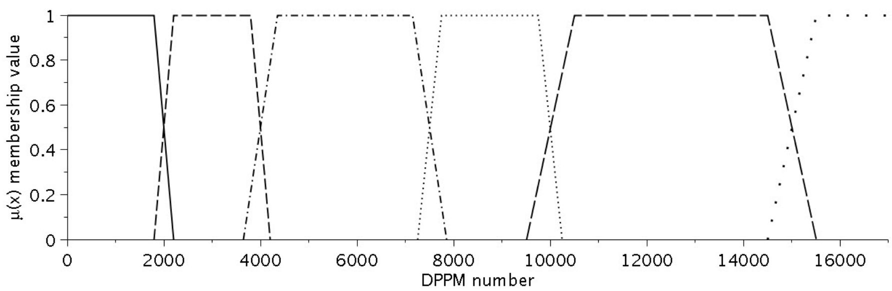

Figure 3. The trapeze fuzzy membership functions at $H = 40$ % by line legs.

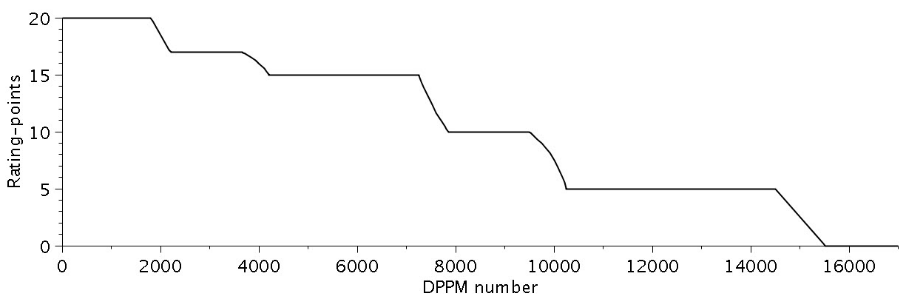

Figure 4. The rating-points at $H = 40$ % used line legs trapeze fuzzy membership function.

$$= \frac{(-p_i b_{i+1} + p_i a_{i+1} + p_{i+1} d_i - p_{i+1} c_i)\, x + p_i d_i b_{i+1} - p_i d_i a_{i+1} - p_{i+1} d_i a_{i+1} + p_{i+1} a_{i+1} c_i}{(-b_{i+1} + a_{i+1} + d_i - c_i)\, x + d_i b_{i+1} - 2\, d_i a_{i+1} + a_{i+1} c_i}$$

if $x \in [c_i, d_i] \cap [a_{i+1}, b_{i+1}]$ and $i \in \{1, 2, 3, 4, 5\}$. The next step is to give the fuzzy membership functions which are in Table 2.

Table 2

The classical trapeze fuzzy membership functions with rate set-transition $H \in]0, 1]$

i	Fuzzy membership function	Mark (p_i)
1.	$[0, 0, 2000 - 500 \cdot H, 2000 + 500 \cdot H]_{classic}$	20
2.	$[2000 - 500 \cdot H, 2000 + 500 \cdot H, 4000 - 500 \cdot H, 4000 + 500 \cdot H]_{classic}$	17
3.	$[4000 - 875 \cdot H, 4000 + 875 \cdot H, 7500 - 875 \cdot H, 7500 + 875 \cdot H]_{classic}$	15
4.	$[7500 - 625 \cdot H, 7500 + 625 \cdot H, 10000 - 625 \cdot H, 10000 + 625 \cdot H]_{classic}$	10
5.	$[10000 - 1250 \cdot H, 10000 + 1250 \cdot H, 15000 - 1250 \cdot H, 15000 + 1250 \cdot H]_{classic}$	5
6.	$[15000 - 1250 \cdot H, 15000 + 1250 \cdot H, 0, 0]_{classic}$	0

The best way to prove the statement is to use computer algebra system like Maple 14. This is good for symbolical and numerical computation. To prove convexity or concavity the second derivative of $M(x)_{i,i+1}$ is used. Generally the first derivative of $M(x)_{i,i+1}$ is

$$M(x)'_{i,i+1} = \frac{(-b_{i+1} + a_{i+1})(-p_{i+1} + p_i)(-d_i + c_i)(-d_i + a_{i+1})}{((-b_{i+1} + a_{i+1} + d_i - c_i)x + d_i b_{i+1} - 2 d_i a_{i+1} + a_{i+1} c_i)^2}$$

and the second derivative of $M(x)_{i,i+1}$ is

$$M(x)''_{i,i+1} = -2\frac{(-b_{i+1} + a_{i+1})(-p_{i+1} + p_i)(-d_i + c_i)(-d_i + a_{i+1})(-b_{i+1} + a_{i+1} + d_i - c_i)}{((-b_{i+1} + a_{i+1} + d_i - c_i)x + d_i b_{i+1} - 2 d_i a_{i+1} + a_{i+1} c_i)^3}.$$

Now, the Rating-point should be provided which is presented in Table 3. according to the classical fuzzy membership functions on Table 2.

Table 3

The Rating-point with function $\mu(x)_{classic}$ and proportional set-transition $H \in]0, 1]$

$M(x)_{i,i+1}$	$M(x)''_{i,i+1}$	Interval
$M(x)_{1,2} = \frac{6000+18500H-3x}{1000H}$	$M(x)''_{1,2} = 0$	$[2000 - 500 \cdot H, 2000 + 500 \cdot H]$
$M(x)_{2,3} = \frac{236000+112000H-59x}{12000+7000H-3x}$	$M(x)''_{2,3} = \frac{-462000H}{(12000+7000H-3x)^3}$	$[4000 - 500 \cdot H, 4000 + 500 \cdot H]$
$M(x)_{3,4} = \frac{5(7500+21875H-x)}{2(-7500+4375H+x)}$	$M(x)''_{3,4} = \frac{131250H}{(-7500+4375H+x)^3}$	$[7500 - 625 \cdot H, 7500 + 625 \cdot H]$
$M(x)_{4,5} = \frac{15(10000+1250H-x)}{-x+2500H+10000}$	$M(x)''_{4,5} = \frac{-37500H}{(-x+2500H+10000)^3}$	$[10000 - 625 \cdot H, 10000 + 625 \cdot H]$
$M(x)_{5,6} = \frac{-45000+6875H+3x}{625H}$	$M(x)''_{5,6} = 0$	$[15000 - 1250 \cdot H, 15000 + 1250 \cdot H]$

So to prove now the existence, it is enough to choose transient phases.
Let it be $H \in]0, 1]$, $M(x)_{2,3}$, $M(x)_{3,4}$ and $M(x)_{4,5}$, their second derivate are strictly monotone and continues functions on the given intervals. Therefore $M(4000 - 500 \cdot H)''_{2,3} = \frac{-462000}{(8500 \cdot H)^3} < 0\ \forall H \in]0, 1]$ *and* $M(4000 + 500 \cdot H)''_{2,3} = \frac{-462000}{(5500 \cdot H)^3} < 0\ \forall H \in]0, 1]$, so the curve is concave because the second derivative is negative on the given interval. *Hence* $M(7500 - 625 \cdot H)''_{3,4} = \frac{131250 \cdot H}{(3750 \cdot H)^3} > 0\ \forall H \in]0, 1]$ *and* $M(7500 + 625 \cdot H)''_{3,4} = \frac{131250 \cdot H}{(5000 \cdot H)^3} > 0\ \forall H \in]0, 1]$, so the curve is convex because the second derivative is positive on the given interval. For $M(10000 - 625 \cdot H)''_{4,5} = \frac{-37500 \cdot H}{(3125 \cdot H)^3} < 0\ \forall H \in]0, 1]$ *and*

$M\,(10000 + 625 \cdot H)''_{4,5} = \frac{-37500 \cdot H}{(1875 \cdot H)^3} < 0\ \forall H \in\ ]0,1]$, so the curve is concave because the second derivative is negative on the given interval. Therefore the existence is proved. □

So the classical trapeze fuzzy membership functions provide three different ratings such as line, convex and concave curves on transient phases. Therefore other kinds of membership functions should be used.

3. Trapeze fuzzy membership function with trigonometrical legs

In this section it will be given the general equation for trapeze fuzzy membership function with trigonometrical legs, it is shown in equation (3.1).

Definition 3.1. The next equation is called trapeze fuzzy membership function with trigonometrical legs:

$$\mu(x)_{trig} = \begin{cases} \frac{1}{2} + \frac{1}{2} \cdot sin(a \cdot x + b) & \text{if } x_1 \le x < x_2, \quad a = \frac{\pi}{x_1 - x_2}, \quad b = \pi \cdot \left(\frac{3}{2} - \frac{x_1}{x_1 - x_2}\right) \\ 1 & \text{if } x_2 \le x \le x_3 \\ \frac{1}{2} + \frac{1}{2} \cdot cos(a \cdot x + b) & \text{if } x_3 < x \le x_4, \quad a = \frac{-\pi}{x_3 - x_4}, \quad b = \frac{\pi \cdot x_3}{x_3 - x_4} \\ 0 & \text{otherwise} \end{cases} \tag{3.1}$$

Here the $x_1,\ x_2,\ x_3$ and x_4 are real points on the abscissa ordered increasingly which have next values:

$$\mu\,(x_1) = 0,\ \mu\,(x_2) = 1,\ \mu\,(x_3) = 1 \text{ and } \mu\,(x_4) = 0. \tag{3.2}$$

The short sign for it is $\mu\ (x)_{trig} \ =\ [x_1, x_2, x_3, x_4]_{trig}$.

In every case the set-transition is chosen as symmetric one. The first and the last fuzzy membership functions were chosen as half of set-transition H — it is shown e.g. on Fig. 5. and Fig. 6, because of the principle of symmetric division is close enough to real application.

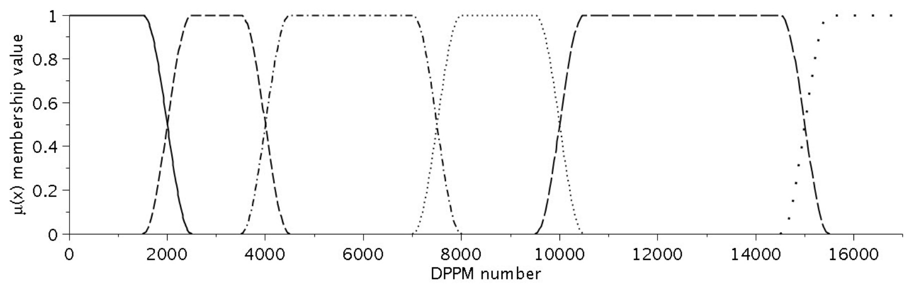

Figure 5. The fuzzy membership functions at $H = 2000$ by trigonometrical legs.

3.1. Constant set-transition in rating-points

In this part next set-transition are chosen $H = 200$ on Fig. 7 and Fig. 8., $H = 400$ on Fig. 9 and Fig. 10., $H = 800$ on Fig. 11 and Fig. 12., $H = 2000$ on Fig. 5 and Fig. 6..

In this case the set-transition is the same for all fuzzy membership function. Therefore set-sizes are not to taken into consideration. Let it be an example here to fuzzyfy in Table 1. the second group: if the set-transition $H = 2000\ DPPM$ then e.g. on Fig. 5 and Fig. 6. for the second membership function the H should be divided into two part so it will be symmetric. For the left side it is $x_1 = 1500\ DPPM$, $x_2 = 2500\ DPPM$, $x_3 = 3500\ DPPM$ and $x_4 = 4500\ DPPM$ so it is provided the second fuzzy membership function according to equation (3.1). Of course to have the rating-points to the given number DPPM it should be taken the equation (2.2).

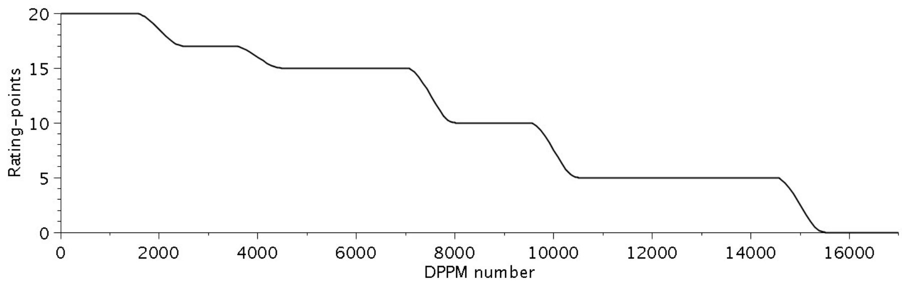

Figure 6. The Rating-point at $H = 2000$.

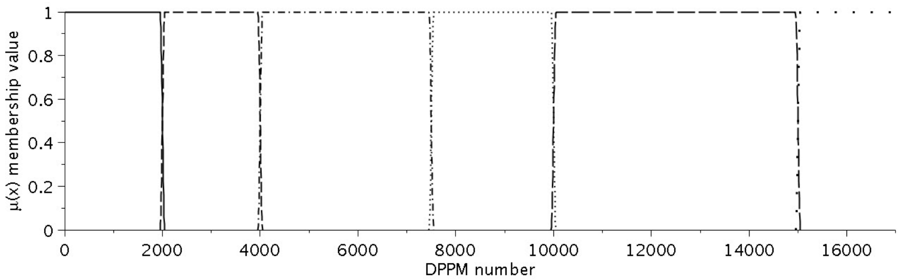

Figure 7. The fuzzy membership functions at $H = 200$ by trigonometrical legs.

3.2. Proportion (rate) set-transition in rating-points

In this part the set-transition takes into consideration the set-size. The next set-transition were chosen by authors: $H = 10$ % on Fig. 13. and Fig. 14., $H = 20$ % on Fig. 15. and Fig. 16., $H = 100$ % on Fig. 19. and Fig. 20. Let it be again an example. Take the third group from the Table 1. and $H = 20\%$ it is shown on Fig. 15 and Fig. 16. the third membership function. So the set-size takes 3500 $DPPM$ therefore it is $H = 0.2 \cdot 3500 = 700$. After this point the method is according to the previous section, so the fuzzy membership function is given with points $x_1 = 3825$ $DPPM$, $x_2 = 4175$ $DPPM$, $x_3 = 7325$ $DPPM$ and $x_4 = 7675$ $DPPM$ according to equation (3.1). Of course the rating-point is evaluated with equation (2.2).

In Table 4, Table 5 and Table 6 it can be seen, there is always an inflexion point according to numerical computation on the given interval and it is always turned from concave to convex as the signum column shows. The proof that there exists inflexion point on every transient phases with changing from concave to convex using proportional set-transition by trigonometrical legs computing with two legs only, is to

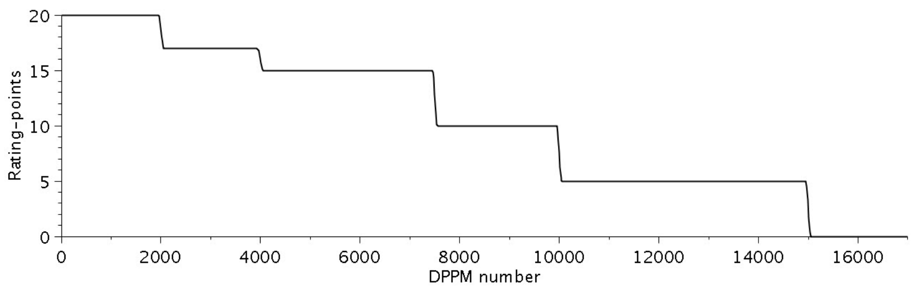

Figure 8. The Rating-point at $H = 200$.

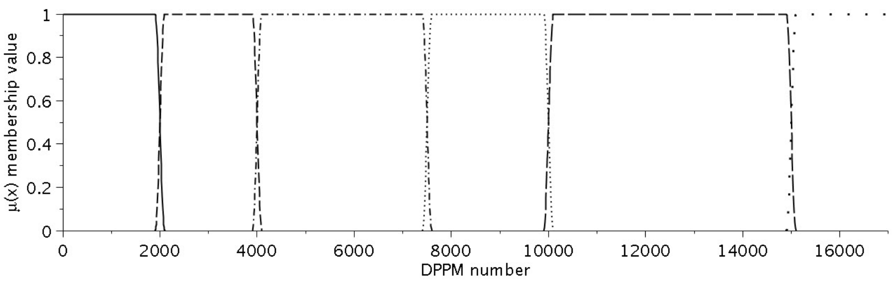

Figure 9. The fuzzy membership functions at $H = 400$ by trigonometrical legs.

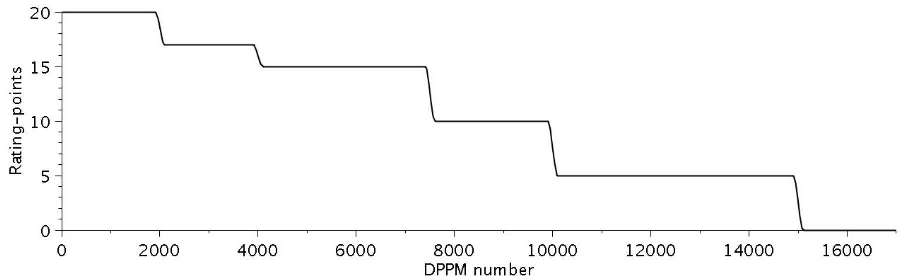

Figure 10. The Rating-point at $H = 400$.

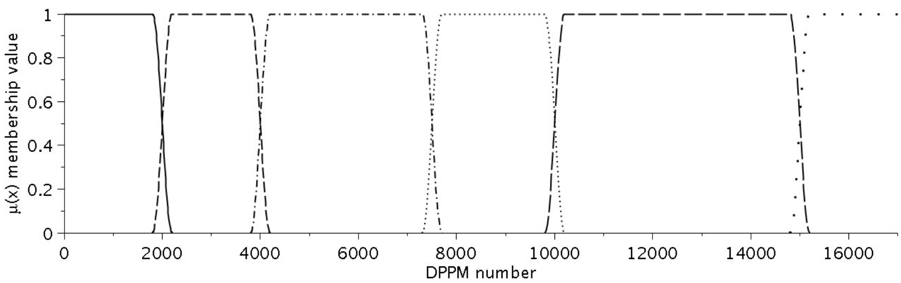

Figure 11. The fuzzy membership functions at $H = 800$ by trigonometrical legs.

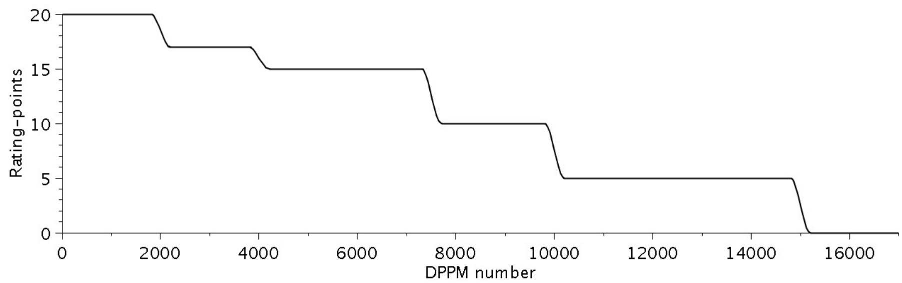

Figure 12. The Rating-point at $H = 800$.

be difficult because the formula is too complicate therefore it is investigated numerically. Generally the

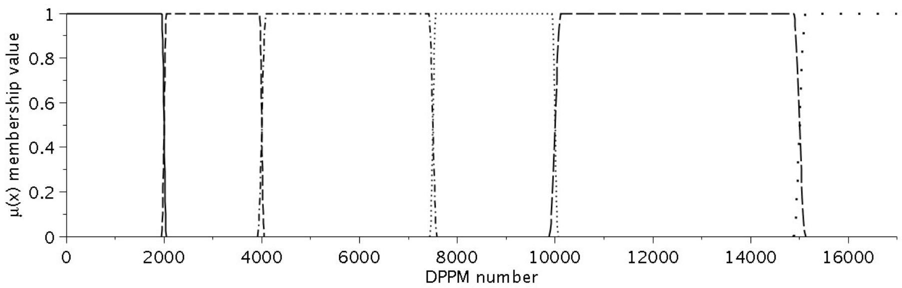

Figure 13. The fuzzy membership functions at H = 10% by trigonometrical legs.

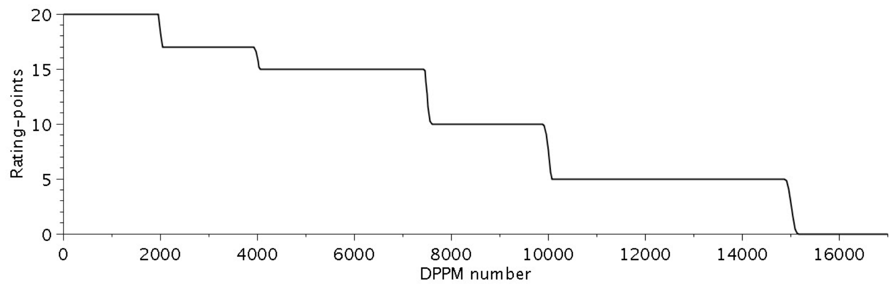

Figure 14. The Rating-point at H = 10%.

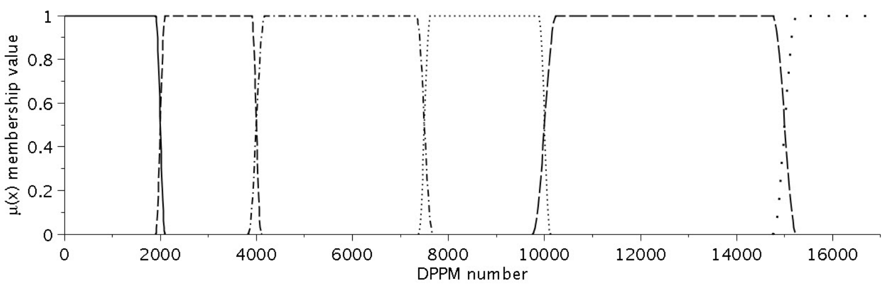

Figure 15. The fuzzy membership functions at H = 20% by trigonometrical legs.

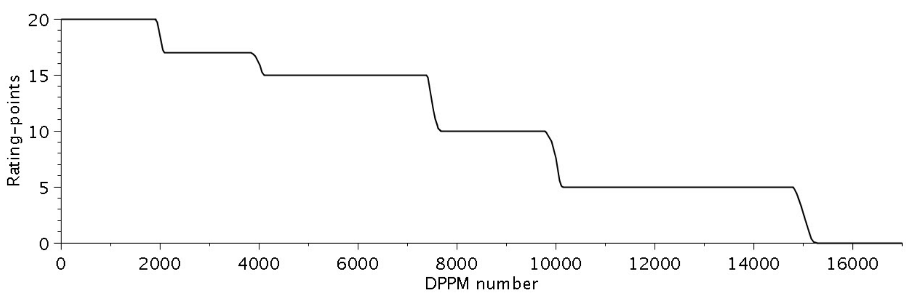

Figure 16. The Rating-point at H = 20%.

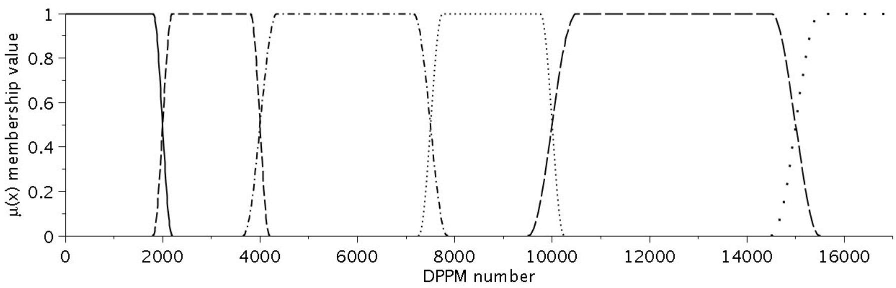

Figure 17. The fuzzy membership functions at $H = 40\%$ by trigonometrical legs.

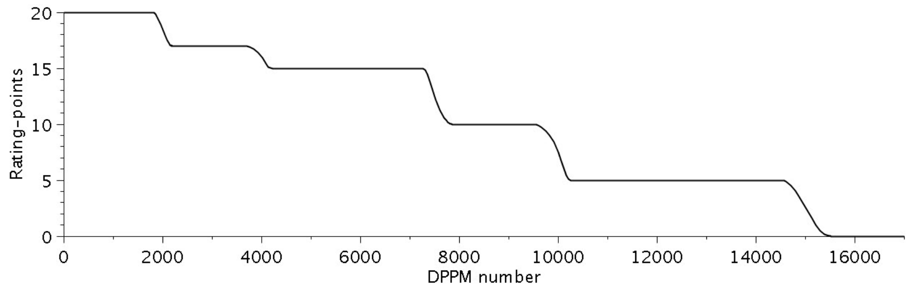

Figure 18. The Rating-point at $H = 40\%$.

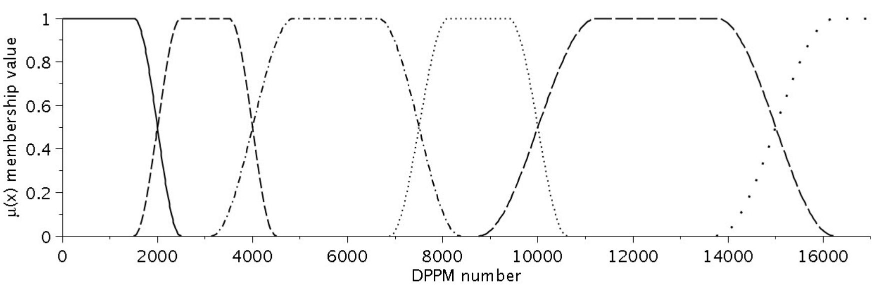

Figure 19. The fuzzy membership functions at $H = 100\%$ by trigonometrical legs.

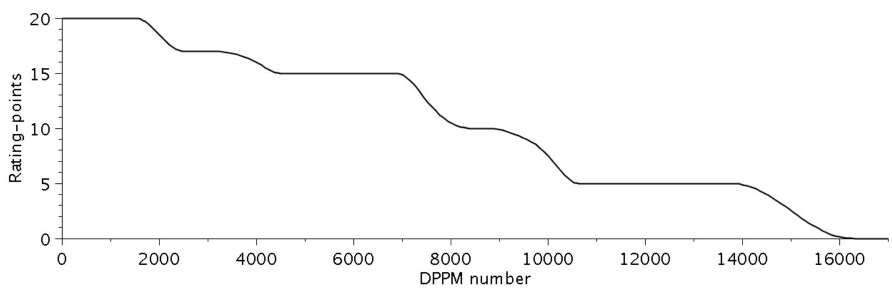

Figure 20. The Rating-point at $H = 100\%$.

equation is on transient phase according to equation (2.2):

$$M_{i,i+1}(x) = \frac{p_i + p_i \cos\left(\frac{\pi(x-c_i)}{c_i-d_i}\right) + p_{i+1} + p_{i+1}\sin\left(\frac{1}{2}\frac{\pi(2x+a_{i+1}-3b_{i+1})}{a_{i+1}-b_{i+1}}\right)}{2+\cos\left(\frac{\pi(x-c_i)}{c_i-d_i}\right) + \sin\left(\frac{1}{2}\frac{\pi(2x+a_{i+1}-3b_{i+1})}{a_{i+1}-b_{i+1}}\right)} \tag{3.3}$$

if $x \in [c_i, d_i] \cap [a_{i+1}, b_{i+1}]$, $i \in \{1, 2, 3, 4, 5\}$ and the fuzzy membership functions are given with $[a_i, b_i, c_i, d_i]_{trig}$ and $[a_{i+1}, b_{i+1}, c_{i+1}, d_{i+1}]_{trig}$. The inflexion point is always $x = 2000$ DPPM for $M_{1,2}(x)$ by different $H \in]0, 1]$ and for $M_{5,6}(x)$ the inflexion point is always at $x = 15000$ DPPM by different $H \in]0, 1]$ on the given interval. The other results are shown in Table 4 and Table 5. The Table 4, the Table 5 and the Table 6 contain the next columns: first column is the set-transition H, the second one is inflexion point for $M_{i,i+1}$ for $i \in \{2, 3, 4\}$, the third one is the Signum column which contain the sign changes of area of inflexion point and the forth one is the given interval for each H. All calculation was made with Maple 14^{th} on a DELL Vostro laptop with 4 cores and 4 GB memory using Windows 7 operation system. To evaluate one rating point it was not measurable the computation time. For example to compute the Table 6 it takes 4.898 seconds.

Table 4

Numerical computation for inflexion point by different $H \in]0, 1]$ for $M_{2,3}$

H	$M_{2,3}$ Inf.p.	Signum	Interval
0.05	4006.842812	[-1,1]	[3975.0, 4025.0]
0.1	4013.685624	[-1,1]	[3950.0, 4050.0]
0.15	4020.528438	[-1,1]	[3925.0, 4075.0]
0.2	4027.371250	[-1,1]	[3900.0, 4100.0]
0.25	4034.214061	[-1,1]	[3875.0, 4125.0]
0.3	4041.056878	[-1,1]	[3850.0, 4150.0]
0.35	4047.899688	[-1,1]	[3825.0, 4175.0]
0.4	4054.742502	[-1,1]	[3800.0, 4200.0]
0.45	4061.585315	[-1,1]	[3775.0, 4225.0]
0.5	4068.428126	[-1,1]	[3750.0, 4250.0]
0.55	4075.270940	[-1,1]	[3725.0, 4275.0]
0.6	4082.113750	[-1,1]	[3700.0, 4300.0]
0.65	4088.956563	[-1,1]	[3675.0, 4325.0]
0.7	4095.799377	[-1,1]	[3650.0, 4350.0]
0.75	4102.642190	[-1,1]	[3625.0, 4375.0]
0.8	4109.485001	[-1,1]	[3600.0, 4400.0]
0.85	4116.327815	[-1,1]	[3575.0, 4425.0]
0.9	4123.170628	[-1,1]	[3550.0, 4450.0]
0.95	4130.013442	[-1,1]	[3525.0, 4475.0]
1	4136.856253	[-1,1]	[3500,4500]

Table 5
Numerical computation for inflexion point by different $H \in]0, 1]$ for $M_{3,4}$

H	$M_{3,4}$ Inf.p.	Signum	Interval
0.05	7493.944539	[-1,1]	[7468.75, 7531.25]
0.1	7487.889079	[-1,1]	[7437.5, 7562.5]
0.15	7481.833616	[-1,1]	[7406.25, 7593.75]
0.2	7475.778155	[-1,1]	[7375.0, 7625.0]
0.25	7469.722696	[-1,1]	[7343.75, 7656.25]
0.3	7463.667234	[-1,1]	[7312.5, 7687.5]
0.35	7457.611773	[-1,1]	[7281.25, 7718.75]
0.4	7451.556308	[-1,1]	[7250.0, 7750.0]
0.45	7445.500850	[-1,1]	[7218.75, 7781.25]
0.5	7439.445389	[-1,1]	[7187.5, 7812.5]
0.55	7433.389928	[-1,1]	[7156.25, 7843.75]
0.6	7427.334467	[-1,1]	[7125.0, 7875.0]
0.65	7421.279003	[-1,1]	[7093.75, 7906.25]
0.7	7415.223545	[-1,1]	[7062.5, 7937.5]
0.75	7409.168084	[-1,1]	[7031.25, 7968.75]
0.8	7403.112621	[-1,1]	[7000.0, 8000.0]
0.85	7397.057160	[-1,1]	[6968.75, 8031.25]
0.9	7391.001700	[-1,1]	[6937.5, 8062.5]
0.95	7384.946237	[-1,1]	[6906.25, 8093.75]
1	7378.890776	[-1,1]	[6875,8125]

Table 6

Numerical computation for inflexion point by different $H \in]0,1]$ for $M_{4,5}$

H	$M_{4,5}$ Inf.p.	Signum	Interval
0.05	10009.65208	[-1,1]	[9968.75, 10031.25]
0.1	10019.30417	[-1,1]	[9937.5, 10062.5]
0.15	10028.95624	[-1,1]	[9906.25, 10093.75]
0.2	10038.60833	[-1,1]	[9875.0, 10125.0]
0.25	10048.26041	[-1,1]	[9843.75, 10156.25]
0.3	10057.91249	[-1,1]	[9812.5, 10187.5]
0.35	10067.56458	[-1,1]	[9781.25, 10218.75]
0.4	10077.21666	[-1,1]	[9750.0, 10250.0]
0.45	10086.86874	[-1,1]	[9718.75, 10281.25]
0.5	10096.52083	[-1,1]	[9687.5, 10312.5]
0.55	10106.17291	[-1,1]	[9656.25, 10343.75]
0.6	10115.82499	[-1,1]	[9625.0, 10375.0]
0.65	10125.47707	[-1,1]	[9593.75, 10406.25]
0.7	10135.12916	[-1,1]	[9562.5, 10437.5]
0.75	10144.78123	[-1,1]	[9531.25, 10468.75]
0.8	10154.43332	[-1,1]	[9500.0, 10500.0]
0.85	10164.08541	[-1,1]	[9468.75, 10531.25]
0.9	10173.73749	[-1,1]	[9437.5, 10562.5]
0.95	10183.38957	[-1,1]	[9406.25, 10593.75]
1	10193.04165	[-1,1]	[9375, 10625]

4. Application of methods

In this section authors provide an example therefore next DPPM numbers are chosen 7500, 7501 and 7510. The evaluation results are in the Table 7. To take into consideration, the proportional set-transition should be always better if the set-sizes are different. Of course to choose the correct DPPM number, one should take opinion and experiences of experts or managers. This method and principal can be applied for any other cases where the structure allowed that.

On the other hand, in the paper (Portik *et al.*, 2011) the authors examined and presented the differences among the conventional, constant and proportional set-transitions via three concrete samples in a transient phase in order to verify the possibility to get a method, which provide more similar results like human thinking. Three samples were chosen, value at 7500 PPM, 7501 PPM and 7510 PPM. On the classical way, the outcome were 15 points at 7500 DPPM and 10 points at 7501 and 7510 DPPM in the evaluation, while the constant and proportional set-transitions calculations result effected 12,5 points at 7500 DPPM in the second two cases, which means adjustment comparing the classical way.

In this paper the authors have done further evaluation in order to provide further adjustments, with changing set-transition. The rate of the change in the output value is more harmonized with the rate of the change in the input parameters as presented in Table 7. Moreover, in case of 7501 DPPM the supplier gets less then 33.33 % by classical method despite of increasing of failure part was only one piece from one million parts. The result was 12.47 points at 7501 DPPM for $H = 20$ % in Table 7, the rate of change was 0.24 % compared to 12.5 rating points despite of 33.33 % when the DPPM changed only with 0.0001 % . The calculation is 12.23 points at 7510 DPPM for $H = 20$ %, the rate of change was 2.16 %. The authors have achieved their aim namely to have a good rate on transient phases.

Table 7
Results of application of methods

	Point belongs to the given number of DPPM		
Methods	7500 *DPPM*	7501 *DPPM*	7510 *DPPM*
Conventional	15	10	10
Constant set-transition			
$H = 200$ *DPPM*	12.5	12.42	11.72
$H = 400$ *DPPM*	12.5	12.46	12.11
$H = 800$ *DPPM*	12.5	12.48	12.3
$H = 2000$ *DPPM*	12.5	12.49	12.42
Proportional set-transition			
$H = 10$ %	12.5	12.44	11.98
$H = 20$ %	12.5	12.47	12.23
$H = 40$ %	12.5	12.48	12.36
$H = 100$ %	12.5	12.49	12.44

5. Conclusion

In this paper the authors provided new results which fulfill the principle of good rating on transient phases. In earlier results of (Portik *et al.*, 2011) it was not good rating on transient phases because on some transient phases there are somewhere convex and somewhere else concave, it is shown on Fig. 4 and Fig. 3. Also in this paper, the authors have achieved the next result: to have a good rating on all transient phases which means the convex and concave transient phases are disappeared. Also it is a good principle for rating suppliers by trapeze fuzzy membership function with trigonometrical legs and with proportional set-transition.

The authors emphasize, the results of this paper can be used in every field, which follows the group-based classification with crisp boundaries for the evaluation. This means wide range of applications in quality assurance, risk assessment, audit results evaluation etc.

One of the authors working in the industry as a quality engineer for years. Previously in electronic, now in automotive industry. The original problem was raised up by him. After the authors search in the scientific literature in order to find any solution to develop this issue, they have started to work out a method to improve. The calculation with sample values illustrated the better distribution of values at the group borders thanks to the new calculation concept. Due to this, the change of the output will be more similar to the change of the input providing a more realistic evaluation. The authors' theoretical and industrial experiences confirm the results.

The authors' plan for the future is to examine other applications to get a comprehensive overview of the efficiency of the method shown in this paper.

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