



DYNAMIC MODEL OF REGULAR SUPPLIER EVALUATION

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Abstract: *The paper presents the shortcomings of static system of regular evaluation of suppliers based on the assumption that the evaluation criteria, their weights and the classification scale for the classification of suppliers into performance groups are fixed. The static system distorts the final evaluation in cases where the potential suppliers cannot be evaluated according to all the criteria during the monitored period. The reason for that is the absence of relevant values of certain criteria. The objective of this article is to eliminate this problem through a dynamic system of suppliers' evaluation in which the values of weights and the classification scale automatically adapt to the number of the actually evaluated criteria.*

Key words: *Supplier evaluation, Multi-criteria methods, Dynamic model*

1 INTRODUCTION

There is very much supplier evaluation and selection approaches in related literature (e.g. [1], [2]). Multi-criteria scoring find the most widespread application [3]. These approaches generally involve extracting and constructing a system of multidimensional criteria, which should be considered together in supplier assessment [4]. The recommended techniques of regular evaluation of suppliers are based on the assumption that each supplier is evaluated according to the pre-selected criteria with clearly assigned weights. The classification of suppliers into groups is also determined using a uniform classification scale. Because the criteria, their weights and the classification scales are invariable, the above specified method of evaluation can be described as static.

In the real entrepreneurial environment, however, there are frequent situations when certain criteria of evaluation cannot be used in the monitored period:

- How to evaluate suppliers in terms of reliability of supplies when a supplier has not delivered anything in the given period of time? At the same time, however, the supplier meets other criteria of evaluation such as communication, quick response to inquiry or an implemented quality system.
- What to do in case the supplier's evaluation criteria include flexibility of supplies (the ability to respond to specific customer requirements), the speed of processing claims, or the quick response to inquiry, but none of these events had occurred in given period?

The static evaluation of suppliers offers the following possible ways:

- Set the values of criteria which cannot be evaluated at the best level – in this case, however, a supplier can receive a more positive rating not complying with the reality. A supplier can have an average rating of criteria that can be evaluated, but the overrated criteria may improve its overall evaluation.
- Set the values of these criteria at the worst level – it may have analogical impact as in the first case, this way may "damage" the supplier's performance.
- These suppliers will not be evaluated.

That is why none of these methods guarantee the aim of the evaluation of the suppliers – to obtain an objective view of the performance of the suppliers. The goal of this article is to eliminate this problem by designing a dynamic evaluation system of suppliers in which the values of weights and the classification scale automatically adjust to the number of the actually evaluated criteria.

2 METHODOLOGICAL BASIS

A relatively large number of approaches with various informative and algorithmic complexity and a degree of elimination of subjectivity (accuracy of the acquired evaluation results) can be used for multi-criteria evaluation of suppliers (e.g. [5], [6], [7], [8]). When choosing a suitable approach for the dynamic evaluation system of suppliers, the objective was to find such techniques that allow you to:

- Perform evaluation based on primary data, i.e. not on the basis of their transfer using the subjective point scale. In case the primary data are available (for ex. percentage of reliable supplies), their transfer using a point scale (for ex. from 1 to 10 points) leads to unnecessary distortion. Primary data can also be acquired automatically from the company information system, thus saving the time of the purchasing department staff.
- Clearly interpret the final, but also partial evaluation of suppliers (evaluation according to the individual criteria). For this purpose, it is necessary to find techniques whose applications are "legible" in managerial practice.
- Automatically recalculate the weights and the classification scale in case a supplier cannot be evaluated according to certain criteria.

Considering these requirements, the following techniques have been selected for experimental work (as default):

1. Setting the criteria weights based on the order of their importance and arithmetic sequence with difference 1:

$$w_i = \frac{n+1-o_i}{n(n+1)/2} \quad (1)$$

w_i – weight of the i -th criterion

o_i – order of importance of the i -th criterion

$i = 1, 2, \dots, n$

n – total number of criteria

2. Distance based method used for the final evaluation of suppliers based on the formula:

$$D_j = \sum_{i=1}^n w_i \cdot \frac{x_{ij} - x_i^o}{x_i^* - x_i^o} \quad (2)$$

D_j – distance of the j -th supplier from anti-ideal supplier

x_{ij} – value of the i -th criterion for the j -th evaluated supplier

x_i^o – value of the i -th criterion for anti-ideal supplier

x_i^* – value of the i -th criterion for ideal supplier

$j = 1, 2, \dots, m$

m – number of evaluated suppliers

Anti-ideal supplier is represented by the worst (minimum) values in the individual criteria. On the contrary, the ideal supplier is represented by the best (maximum) values in the criteria. The higher the D_j is, the better evaluation the supplier receives. The numerator represents partial distance between assessed supplier and anti-ideal supplier. The denominator guarantees comparability single criteria (transfer into comparable level in range 0 – 1).

3 EXPERIMENTAL WORK

The dynamic evaluation system of suppliers has been developed for a company engaged in engineering industry. The development included the following stages:

1. Setting the evaluation criteria
2. Setting the order of significance of criteria
3. Designing the dynamic calculation of weights
4. Designing the dynamic setting of the classification scale

3.1 Setting the evaluation criteria

Twelve most important criteria for the evaluation of suppliers ($C_1 - C_{12}$), clear indicators for their measuring and minimum, maximum and threshold values of the criteria were determined through controlled interview with the representatives of the company top management. The threshold values identify satisfactory and unsatisfactory level of performance of those criteria (see Table 1).

Tab. 1 Criteria for evaluation of suppliers

Criterion	Measure	Value		
		Min	Max	Threshold
C_1 : Quality of material in input	Value of products excluding claims/total value of supplied products*100 (%)	0	100	85
C_2 : Quality of material in production	Value of products excluding claims/total value of supplied products *100 (%)	0	100	95
C_3 : Reliability of supplies	Number of reliable supplies/total number of supplies*100 (%)	0	100	70
C_4 : Delivery in compliance with DDU terms	Yes/no	0 (No)	1 (Yes)	0
C_5 : Marking of supplies	Number of correctly marked supplies/total number of supplies*100 (%)	0	100	90
C_6 : Flexibility of supplier	Subjective point scale from 1 to 5 points	1	5	1
C_7 : Communication	Subjective point scale from 1 to 5 points	1	5	1
C_8 : How quickly claims are solved	Number of claims solved within 7 days/ number of all claims * 100 (%)	0	100	70
C_9 : Reaction to inquiry	Subjective point scale from 1 to 5 points	1	5	1
C_{10} : Payment terms	Term of expiration (days)	0	60	30
C_{11} : Implemented QMS	Yes/no	0 (No)	1 (Yes)	0
C_{12} : Implemented EMS	Yes/no	0 (No)	1 (Yes)	0

The research concerns mainly suppliers of no homogenous products. Evaluation of suppliers of homogenous products may involve different set of criteria resulting from the use of trading platforms [9].

3.2 Setting the order of significance of criteria

The order of criteria significance has been set on the basis of controlled interviews with the top management of the company and the application of the Fuller triangle. The resulting criteria order is shown in Table 2.

Tab. 2 Order of selected criteria significance

Order of significance	Criterion	Weight
1.	C_1 : Quality of material in input	0.15
2.	C_2 : Quality of material in production	0.14
3.	C_{10} : Payment terms (days)	0.13
4.	C_3 : Reliability of supplies (%)	0.12
5.	C_6 : Flexibility of supplier (1 - 5)	0.10
6.	C_8 : How quickly claims are solved (%)	0.09
7.	C_9 : Reaction to inquiry (1 - 5)	0.08
8.	C_5 : Marking of supplies (%)	0.06
9.	C_4 : Delivery in compliance with DDU terms (yes/no)	0.05
10.	C_7 : Communication (1 - 5)	0.04
11.	C_{11} : Implemented QMS (yes/no)	0.03
12.	C_{12} : Implemented EMS (yes/no)	0.01

3.3 Designing the dynamic calculation of weights

Based on the obtained order of significance and the application of formula (1), the amplitude of weights of the individual criteria can be determined. The values of weights in cases when a supplier can be evaluated according to all the criteria weights are listed in Table 2. In case one or more criteria cannot be evaluated, the remaining criteria will be arranged in new order and formula (1) will be applied as well.

3.4 Designing the dynamic setting of the classification scale

The classification scale is used to include the evaluated supplier into a group which corresponds to its performance. After consultation with the top management of the company, a scale consisting of four groups has been selected:

- A: Trouble-free supplier – in case a supplier is evaluated as a trouble-free one, it is not necessary to take any action.
- B: Supplier with remarks – in case of partial shortcomings, the problem and the solution must be clearly specified with the supplier by means of increased communication. The supplier should confirm the implementation of the corrective measures in written form. Should any shortcomings be experienced repeatedly, a procedure should be put in action for suppliers with remarks.
- C: Supplier with reservations – for the more significant problems, it is necessary for the supplier to accept a program of corrective actions. A "Corrective program" has been designed in cooperation with the purchasing department to serve this purpose. Within the scope of this program, the supplier should specify the corrective actions; designate the responsible people and deadlines for correction. Subsequently, the supplier should clearly demonstrate the implementation of the measures taken. In the event of repeated shortcomings, termination of cooperation can be recommended.
- D: Unsatisfactory supplier – suppliers classified in this group do not meet the minimum

requirements of the company. In this case, we can recommend the cooperation to be terminated.

The following procedure has been selected in order to determine the dynamic boundaries of the individual groups:

1. Determination of the limit values of the classification scale – the logic of the formula (2) tells us that the supplier can achieve evaluation within the range of $< 0; 1 >$, where 0 represents an anti-ideal supplier and 1 an ideal supplier.
2. Dynamic calculation of the boundary for unsatisfactory suppliers – the boundary value for unsatisfactory suppliers can be determined using minimum ($= x_i^o$), maximum ($= x_i^*$) and threshold values of ($= x_{ij}$) of the individual criteria listed in Table 1 in formula (2). For cases where all criteria can be evaluated, the boundary is 0.65. In the event that some criteria cannot be evaluated, the value will be determined from minimum, maximum and threshold values of the remaining criteria.
3. Dynamic calculation of the remaining boundaries – the range between the ideal (evaluation 1) and the unsatisfactory supplier (see previous point) are divided into three equal sections.

In cases when it is possible to evaluate all the criteria, the following classification scale is used:

- Trouble-free supplier $< 0.89; 1 >$
- Supplier with remarks $< 0.77; 0.88 >$
- Supplier with reservations $< 0.65; 0.76 >$
- Unsatisfactory supplier $< 0; 0.64 >$

4 RESULTS AND DISCUSSION

The designed evaluation system was verified for 34 key suppliers of the company. The following part will present the results of evaluation of 4 selected suppliers (S_6, S_7, S_{16}, S_{21}). The values and criteria weights for the individual suppliers are illustrated in Table 3. Different weights of the individual suppliers are caused by different number of criteria which could be used to evaluate the individual suppliers in the monitored period of time.

Tab. 3 Input data for evaluation of selected suppliers

Criterion / Supplier	Values				Weights			
	S_6	S_7	S_{16}	S_{21}	S_6	S_7	S_{16}	S_{21}
C_1 : Quality of material in input (%)	100	100	100	100	0.25	0.22	0.22	0.20
C_2 : Quality of material in production			86.76	90.31			0.19	0.18
C_{10} : Payment terms (days)	30	45	30	45	0.21	0.19	0.17	0.16
C_3 : Reliability of supplies (%)	100	100	100	100	0.18	0.17	0.14	0.13
C_6 : Flexibility of supplier (1 - 5)								
C_8 : How quickly claims are solved (%)		0		0		0.14		0.11
C_9 : Reaction to inquiry (1 - 5)								
C_5 : Marking of supplies (%)	100	100	100	100	0.14	0.11	0.11	0.09
C_4 : Delivery in compliance with DDU	0	0	1	0	0.11	0.08	0.08	0.07
C_7 : Communication (1 - 5)								
C_{11} : Implemented QMS (yes/no)	1	1	1	1	0.07	0.06	0.06	0.04
C_{12} : Implemented EMS (yes/no)	1	0	1	1	0.04	0.03	0.03	0.02

Ranges of classification groups for the individual suppliers are illustrated in Table 4. Again, there are obvious differences caused by different number of evaluated criteria.

Tab. 4 Classification groups for evaluation of selected suppliers

Group / Supplier	S_6	S_7	S_{16}	S_{21}
A: Trouble-free supplier	< 0.86; 1 >	< 0.87; 1 >	< 0.88; 1 >	< 0.89; 1 >
B: Supplier with remarks	< 0.71; 0.85 >	< 0.73; 0.86 >	< 0.77; 0.87 >	< 0.78; 0.88 >
C: Supplier with reservations	< 0.57; 0.70 >	< 0.60; 0.72 >	< 0.65; 0.76 >	< 0.67; 0.77 >
D: Unsatisfactory supplier	< 0; 0.56 >	< 0; 0.59 >	< 0; 0.64 >	< 0; 0.66 >

The final evaluation of suppliers obtained by applying formula (2) and their incorporation into the classification groups are shown in Table 5. The top rated supplier S_{16} was included in category A: Trouble-free supplier. Group B: Supplier with remarks includes supplier S_6 . Suppliers S_7 and S_{21} were placed in Group C: Supplier with reservations.

Tab. 5 The final evaluation of selected suppliers

Criterion / Supplier	S_6	S_7	S_{16}	S_{21}
C_1 : Quality of material in input (%)	0.25	0.22	0.22	0.20
C_2 : Quality of material in production (%)			0.17	0.16
C_{10} : Payment terms (days)	0.11	0.15	0.08	0.12
C_3 : Reliability of supplies (%)	0.18	0.17	0.14	0.13
C_6 : Flexibility of supplier (1 - 5)				
C_8 : How quickly claims are solved (%)		0.00		0.00
C_9 : Reaction to inquiry (1 - 5)				
C_5 : Marking of supplies (%)	0.14	0.11	0.11	0.09
C_4 : Delivery in compliance with DDU terms (yes/no)	0.00	0.00	0.08	0.00
C_7 : Communication (1 - 5)				
C_{11} : Implemented QMS (yes/no)	0.07	0.06	0.06	0.04
C_{12} : Implemented EMS (yes/no)	0.04	0.00	0.03	0.02
D_j	0.79	0.70	0.89	0.77
Classification group	B	C	A	C

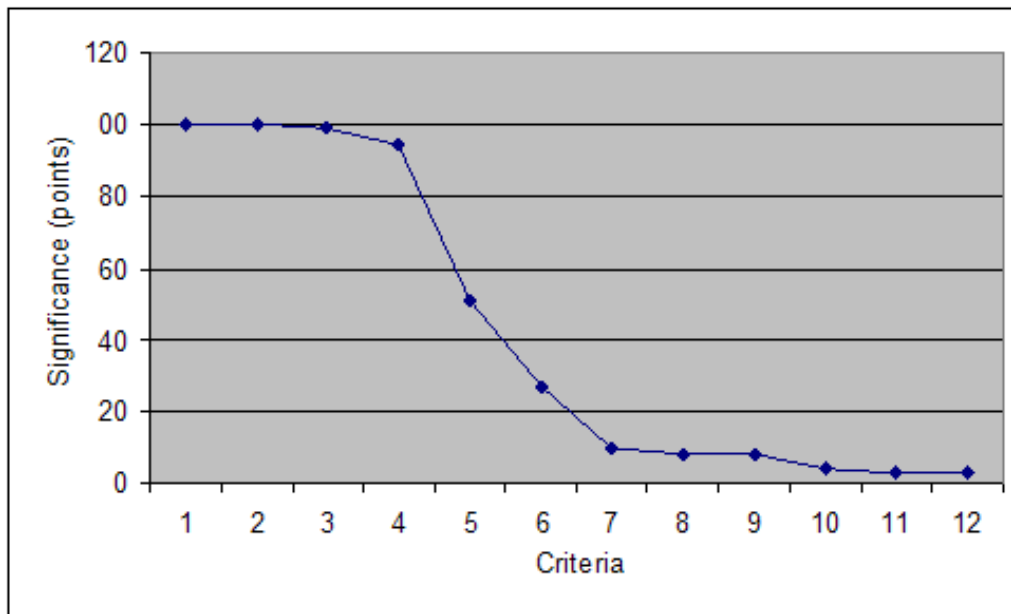
The acquired results were evaluated by the top management which brought forward the cases with disputable evaluation of some of the suppliers. Based on that, the causes of the identified deviations were analyzed and two changes of the proposed system were realized:

1. Specification of the boundaries for categorization of suppliers – based on statistical processing of the input data from the period under evaluation, the threshold values for unsatisfactory suppliers previously determined by an estimate made by the top management have been revised. Comparison of the original and new threshold values is illustrated in Table 6. As a result of this intervention, the boundaries for unsatisfactory suppliers were made more restrictive.

Tab. 6 Comparison of the original and re-evaluated threshold values

Criterion	Threshold limits	
	Original	New
C_1 : Quality of material in input (%)	85	95
C_2 : Quality of material in production (%)	95	99
C_{10} : Payment terms (days)	30	30
C_3 : Reliability of supplies (%)	70	70
C_6 : Flexibility of supplier (1 - 5)	1	1
C_8 : How quickly claims are solved (%)	70	70
C_9 : Reaction to inquiry (1 - 5)	1	1
C_5 : Marking of supplies (%)	90	99
C_4 : Delivery in compliance with DDU terms (yes/no)	0	0
C_7 : Communication (1 - 5)	1	1
C_{11} : Implemented QMS (yes/no)	0	0
C_{12} : Implemented EMS (yes/no)	0	0

2. Change of the method of weights calculation – the original method was based on an arithmetic sequence with difference 1, which resulted in relatively balanced weighting values for all the evaluated criteria. The top management, however, considered the group of the first 4 criteria to be significantly more important than the group of the last 6 criteria. That is why the new calculation has been based on determining the significance of criteria using the point scale score with the range of $< 0; 100 >$, corresponding to the logistic function (see figure 1).

**Fig. 1** Point rating of significance of the individual criteria

Weights illustrated in Table 7 represent the outcome (for cases when a supplier can be evaluated according to all the criteria). For the sake of comparison, the original values are included here as well.

Tab. 7 Newly determined weights

Criterion	Weights	
	Original	New
C_1 : Quality of material in input (%)	0.15	0.20
C_2 : Quality of material in production (%)	0.14	0.20
C_{10} : Payment terms (days)	0.13	0.20
C_3 : Reliability of supplies (%)	0.12	0.19
C_6 : Flexibility of supplier (1 - 5)	0.10	0.10
C_8 : How quickly claims are solved (%)	0.09	0.05
C_9 : Reaction to inquiry (1 – 5)	0.08	0.02
C_5 : Marking of supplies (%)	0.06	0.02
C_4 : Delivery in compliance with DDU terms (yes/no)	0.05	0.02
C_7 : Communication (1 - 5)	0.04	0.01
C_{11} : Implemented QMS (yes/no)	0.03	0.01
C_{12} : Implemented EMS (yes/no)	0.01	0.01

5 CONCLUSIONS

The developed dynamic system used for periodic evaluation of suppliers has removed the shortcomings of static evaluation in cases where it was not possible to evaluate a supplier according to all the criteria in the monitored period of time. Its successful implementation depends on the fulfilment of the following presumptions:

- Transfer of the system into company information system.
- Creation of supporting setups that are going to provide detailed information on the fulfilment of partial criteria in cases when a supplier is classified in the lower performance groups (a setup showing the structure of the reliability of supplies – the number of all deliveries, premature deliveries, the number of late deliveries can serve as an example).
- Definition of responsibilities and discipline in implementation of the input information of the evaluation system.
- Regular review of the system (selected criteria, their order and weights) in approximately two-year cycles. Current economic downturn increases the pressure on financial constraints including the terms of payment [10].

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