

Occupational Health Maturity Model by combined Delphi and Fuzzy comprehensive evaluation methods

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ABSTRACT: There are many strategies to do an assessment of Occupational Health and Safety Maturity (OHS). These strategies depend of the vision of occupational health, human and organizational factors in the institutions. In this paper we focus on the holistic view of occupational health that concerns the operational and human factors management but also the strategic top level of the company. The model is based on a forecasting questionnaires destined to a group of experts. The indicators of each level of the model are associated to questions in the questionnaire. There are two levels of indexation of these indicators. The first step is weighting the three categories of indicators in the first indexation level. The second step is weighting the second level of the indicators in each category. In these two steps of weighting we use Delphi method, a subjective method of weighting. The Third step consists on setting a Fuzzy comprehensive evaluation matrix to define the maturity level of the Occupational Health and Safety. We use another questionnaire to define the level of each indicator of the model. The Fuzzy comprehensive evaluation model gives the vector of maturity scoring by injecting the weightings calculated by Delphi method.

KEYWORDS: Delphi method, Subjective weighting method, OHS Occupational Health and Safety, Maturity matrix, Fuzzy evaluation

I. INTRODUCTION

The evaluation of an OHS maturity level needs a maturity assessment model. Our model is based on Capability maturity model (CMMI) of the Software Engineering Institute (SEI). Four levels are defined for the OHS maturity: «Absent» when OHS measures are not in the agenda of the company, « Basic » when OHS is only a legal obligation and the company acts as a reactive actor in OHS, « Advanced » when the company is proactive to OHS issues and OHS is present in organization and process system and « Institutionalized » when OHS is anchored in the strategy and the company's culture and considered as a lever of global performance.

The maturity model gives as a referential of levels and actions we can implement to improve this level by improving the impactful levers of OHS management. In this paper we develop another methodology in the constitution of the OHS maturity model. We will experiment Delphi method as a subjective weighting method instead of AHP as used in another paper. The evaluation will be estimated by Fuzzy evaluation comprehensive method. The result is a scoring vector defining the level of OHS maturity. This result is analyzed in order to define 1) the impactful indicators that worth the investment to get the desired maturity level and 2) a roadmap of how can we deploy a successful OHS strategy.

II. THE MATURITY MODEL

Overview: OHS is considered as organizational culture: "...the basic values, norms, beliefs, and practices that characterize the functioning of a particular institution...defines the assumptions that employees make as they carry out their work...a powerful force that persists through reorganizations and the departure of key personnel." Columbia Accident Investigation Board The challenge in this research topic is to translate OHS maturity to measurable indicators. That's why a methodology allowing the conversion of qualitative data into quantitative ones is needed.

	OHS area	Indicators
OHS maturity Evaluation	Strategy (M_1)	Sustainability (M_{11}) Organization (M_{12}) Culture (M_{13}) Change management (M_{14})
	Human Resources (M_2)	Career management (M_{21}) Social climate (M_{22}) Wellness awareness (M_{23})
	Operational management (M_3)	Work conditions (M_{31}) Risk management (M_{32}) Safety management (M_{33}) Performance system (M_{34})

Table 1: OHS maturity evaluation area and indicators

this model the assessment concerns three areas representing Strategy, Human Resources and operational aspects. In each area we define indicators. In Strategy we have identified Sustainability, Organization evaluation, OHS Culture and the change management process as indicators. In Human Resources, we identified Career satisfaction, the Social Climate and Wellness awareness. And in the Operational area, we focus on work conditions, Risk, Safety and Performance systems (Table 1). All of these indicators are evaluated according to four levels of maturity in this model: Absent, Basic, Advanced and Institutionalized.

OHS Maturity Framework: For the experimentation, we choose a group of experts to respond to a questionnaire based on the OHS indicators. For each evaluation area we have questions to evaluate the associated indicators from Absent, Basic, Advanced and Institutionalized. The responses represent the first matrix of different evaluation repartition of each indicator by the group of experts. This matrix is called membership matrix in Fuzzy comprehensive evaluation method. The step of weighting is also important to evaluate the raw of each indicator in his category and also the importance each area of evaluation. This weighting in this study will be realized by a subjective method called Delphi method. All these results are injected in the Fuzzy comprehensive method to determine a scoring of OHS maturity. This scoring is the base of a qualitative analysis to determine 1) the impactful indicators and 2) a roadmap of upgrading maturity (Figure 1

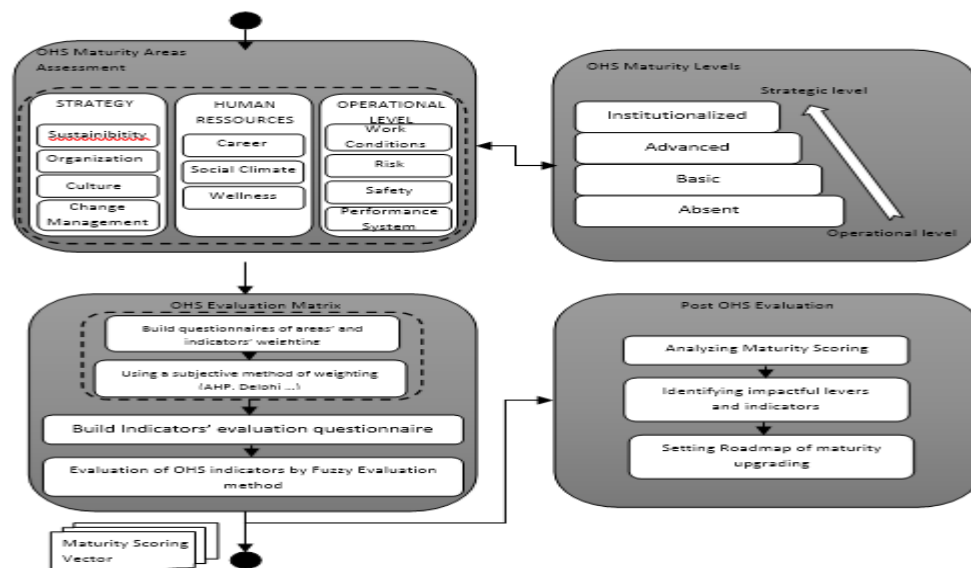


Figure 1: Life cycle of OHS maturity assessment

III. METHODOLOGY

Delphi Method: Delphi method is considered as Multi criterion Decision-Making (MCDM). It is a subjective weighting method. Delphi method is characterized by anonymity, feedback and convergence. In Delphi context anonymity means that the experts don't meet when participating in the questionnaire forecast to avoid psychological interferences and influences. Feedback means that Delphi is based on the share and feedback of the information collected in each round of forecast. And Convergence refers to opinions of experts that converge from round to round of forecasting. (Bin, 1998; Keeney et al., 2001; Van Zolingen and Klaassen, 2003). How it works? The questionnaire about the importance of indicators is used to calculate the score of each indicator. The group of experts fill the questionnaire according five levels of importance (Table 2), in each round of forecasting. After many iteration the values of evaluation are converging then the weighting coefficients of the indicators are calculated in equations (a) and (b):

$$\check{S}_j = \frac{\sum_{p=1}^M S_p^j}{M} \quad (a)$$

$$W^{delphi} = \{\omega_j^{delphi}\} = \left\{ \frac{\check{S}_j}{\sum_{i=1}^N \check{S}_j} \right\} \quad (b)$$

Where M is the number of experts,

And N is the number of indicators

S_p^j The Score given by the expert p for the indicator j

W^{delphi} is the weighting coefficient vector

ω_j^{delphi} is the weighting coefficient calculated by Delphi method

Indicator	Lowly Important	Medium Important			Highly Important
	1	2	3	4	5
M ₁₁		√			
M ₁₂				√	
M ₁₃			√		
M ₁₄	√			√	
M ₂₁			√		
M ₂₂		√			
M ₂₃		√			
M ₃₁			√		
M ₃₂			√		
M ₃₃				√	
M ₃₄	√				

Table 2 : Exemple of Delphi questionnaire for indicators' importance

Comprehensive Fuzzy evaluation method: Maturity scoring vector, which is used to determine the OHS maturity, is calculated by the Fuzzy evaluation method. The matrix of evaluation concerns the amount of the level evaluation for each OHS indicator from a lower to a higher level of OHS maturity (Absent, Basic, Advanced, Institutionalized). The questionnaire used for this step is constituted with more than fifty questions to evaluate the different aspects of OHS listed in Table 1. Principals of comprehensive fuzzy evaluation is to define the membership of OHS maturity matrix which is the evaluation matrix R_{ijk} :

$$R_{ijk} = \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{ij1} & r_{ij2} & \cdots & r_{ijm} \end{bmatrix} \quad (1)$$

(Wang Jian, Xu Ya-bo in *Application of Fuzzy Mathematics, Safety Evaluation, Theory and Research 2* (2005)).

$$R_{ij} = W_{ij} \circ R_{ijk} \quad (2)$$

$$[w_{i1} \ w_{i2} \ \cdots \ w_{im}] \circ \begin{bmatrix} r_{i11} & r_{i12} & \cdots & r_{i1m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{ij1} & r_{ij2} & \cdots & r_{ijm} \end{bmatrix} = [r_{i1} \ r_{i2} \ \cdots \ r_{im}] \quad (3)$$

(\circ is the fuzzy operator)

Where $k = 1, 2, \dots, m$,

m is the evaluation level,

i is the class indexes (OHS area) number,

and j is the second indexes (indicators) number.

W_{ij} The coefficient-weighting vector calculated by Delphi method for the first class index

w_{im} The coefficient weighting calculated by Delphi method for the second class index

(Zhang Jun, Yang Wei-ping, Yang Li-gong in *Application of Fuzzy Comprehensive Evaluation* (2011))

APPLICATION CASE : Twenty experts are involved to evaluate the OHS maturity from the defined area. In addition, five experts are interviewed for the weighting process by Delphi method during five iterations. The context concerns a financial structure.

The weight result of the second class index are shown in Table 3:

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	$S_{(Mij)}$	W^{delphi}
M_{11}	3	3	3	3	3	3	0,231
M_{12}	3	3	3	3	3	3	0,231
M_{13}	4	4	4	4	4	4	0,308
M_{14}	3	3	3	3	3	3	0,231
M_{21}	3	3	3	3	3	3	0,273
M_{22}	4	4	4	4	4	4	0,364
M_{23}	4	4	4	4	4	4	0,364
M_{31}	3	3	3	3	3	3	0,273
M_{32}	3	3	3	3	3	3	0,273
M_{33}	3	3	3	3	3	3	0,273
M_{34}	2	2	2	2	2	2	0,182

Table 3: Delphi weighting of the second-class index

The weight result of the first class index are shown in Table 4:

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	$S_{(M_i)}$	W^{delphi}
M1	4	5	4	3	4	4	0,357
M2	3	2	3	3	4	3	0,268
M3	3	5	4	4	5	4,2	0,375

Table 4: Weighting results of the first class index by Delphi method

And membership results of the second-class index are shown in Table 5.

1st class index	2nd class index	Maturity Level			
		Institutionalized	Advanced	Basic	Absent
M_i	M_{ij}				
M1	M11	0	0,1	0,5	0,4
	M12	0	0,7	0,3	0
	M13	0	0,4	0,6	0
	M14	0,4	0,6	0	0
M2	M21	0,4	0,6	0	0
	M22	0	0,2	0,8	0
	M23	0	0	0,6	0,4
M3	M31	0	0,3	0,7	0
	M32	0	0,2	0,6	0,2
	M33	0	0,2	0,8	0
	M34	0,2	0,5	0,3	0

Table 5: Membership of the second-class index

The first class index membership by fuzzy comprehensive evaluation and the weights of the first class index are shown in Table 6.

After the application of our OHS maturity evaluation model, we reach these results:

Let's put M as the vector of OHS maturity level, $M = W^{delphi}R$.

W^{delphi} is the first class index vector (Table 4)

R is the first class index membership matrix (Table 6)

Numerically, we get the value of OHS maturity level like that:

$$M = (0.07582418; 0.32833417; 0.50345904; 0.09238262)$$

R	Institutionalized	Advanced	Basic	Absent
M1	0,09230769	0,44615385	0,36923077	0,09230769
M2	0,10909091	0,23636364	0,50909091	0,14545455
M3	0,03636364	0,28181818	0,62727273	0,05454545

Table 6: Maturity membership matrix of the first class index

IV. ANALYSIS OF THE RESULTS

According to the maximum membership degree principle, the OHS maturity level in the calculated vector M is Basic level where the structure is in a reactive posture in front of the exterior requirements and policy obligations. We can also observe that the level “Advanced” is also consistent compared to the other levels “Institutionalized” an “Absent”. The level of maturity can be considered as “Basic” with a big tendency to the superior level “Advanced”. The structure doesn’t need to invest a lot to get the level “Advanced in this case. As recommendations, we can identify some impactful levers to get easily the “Advanced” level. In this example, we observe that the most important weight of the OHS area evaluation is almost equivalent. That’s why we can consider an analysis of the second-class index corresponding here to the indicators. The most impactful indicator is the Social Climate and the Wellness awareness. OHS culture has also an important impact to OHS maturity. That’s why it is interesting to invest on the Social Climate, Wellness and Culture as a first step to enhance OHS maturity in this structure. We can also observe that this model can be used in different contexts and the investment decisions are down top because the experts represents a good sample of the population in the structure, and the weighting of the impactful factors on OHS maturity are also collected from the experts in the structure. Delphi method is different from AHP in the approach even if they are both subjective methods of weighting. Delphi is an iterative method because we look for a consensus of the experts and give them the opportunity the review their forecasts. At the same time, it mobilizes the experts many times especially in the iteration effort.

V. CONCLUSION

In this study we took the challenge to mobilize experts and stakeholders more than the AHP study in a previous paper. The results are comparable. It will be relevant to calculate the sensitivity and the consistency of the weighting matrix obtained by Delphi to compare the methods. Again, this paper contributes with another way of OHS maturity assessment by following a strong framework based on Fuzzy evaluation method and simple to enforce and implement. The strength of this model is its independence from the activity of the structure because it concerns Strategy, HR and operational management that are common to all institutions and structures. This model can evolve depending on area of assessment we target. Whether subjective or objective, with the assumption of uncertainty in importance, the data source will determine the weighting method to use and the evaluation method to experiment to define maturity of given domain by following the same steps of the above framework.

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