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ASSESSING HUMAN AND ORGANIZATIONAL FACTORS MATURITY EMPLOYING FUZZY ANALYTIC NETWORK PROCESS METHOD

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ABSTRACT

The Human and Organizational Factors (HOF) approach consists in identifying and implementing the conditions that favor a positive contribution of operators and groups to safety. But when implementing this approach, companies find it difficult to define their current HOF maturity level and identify the areas that need improvement first. The HOF maturity model suggested in this article aims to support companies during the accomplishment of a successful and safe human performance. It is composed of six factors and their related HOF characteristics described with key questions to facilitate its implementation. The model is applied in a Moroccan cement plant employing the Fuzzy Analytic Network Process (ANP) technique because of the imprecision of human judgements and the consideration of interactions between the factors.

Keywords: *Human and Organizational Factors, Maturity Model, Safety, Fuzzy Analytic Network Process, Improvement.*

1. INTRODUCTION

Major industrial accidents such as : Seveso, Three Mile Island and Challenger Shuttle Disaster …, gave rise to stricter regulatory requirements (Seveso Directives) and the implementation of safety management system (SMS) [1]. These technical and organizational actions have led to a continuous decrease in process-related accidents in certain sectors. However, in many companies, this improvement has reached a plateau, and the strengthening of formalisms no longer leads to a reduction in failures. To address this issue, it was necessary to integrate the human and organizational factors for the following reasons [2]:

- Emphasize, not only top-down formalisms which are intended to prescribe safe operating conditions, but also bottom-up formalisms.
- Ask more questions about the contribution of the organization and management, rather than search for responsibilities in terms of the behavior of operators,
- Consider the reality of work situations encountered by the operators.

The purpose of developing maturity models is to assist companies seeking to achieve an effective management of HOF, by offering this solution that guides them in determining their current maturity level and identifying the key elements to be improved [3].

In this article is suggested a HOF maturity model, comprised of six principal factors that correspond to companies' standards. Each factor contains the associated HOF sub-factors, which are introduced using the key questions, to have a comprehensible and easy to apply model. For assessing the maturity level among the five proposed, the Fuzzy ANP method is used.

A Moroccan cement plant needed to enhance its maturity for reducing the number of accidents related to the HOF. Consequently, the model is implemented to guide the company during this identification and improvement phase.

The structure of the remaining sections is as follows: The "State of the art" is provided in the first section. The second section introduces structure of the HOF maturity model proposed. Section "Fuzzy ANP method" explains the methodology steps. While section "Case Study" presents the findings obtained. Finally, the section "Conclusion".

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2. STATE OF THE ART

The concept of safety maturity models allows each organization to assess its own level of safety culture maturity, it has been applied in various critical sectors such as the aviation, offshore, mining, rail, and petrochemical industries. It aims to assist companies in determining their maturity level through several key elements related to safety culture, and among a defined number of maturity levels [4].

Table 1 provides an overview of different maturity models, each model suggested five levels of maturity with various elements that impact safety culture [5, 6, 7, 8, 9].

Human error has contributed to major accidents in several industries in the past, for example human errors were involved in 70% of aircraft accidents , for that reason the human factors and safety are part of the same discussion.

The Keil Centre developed The Human Factors Maturity Model (HFMM) to guide organizations not only in assessing their maturity level of human factors, but also in defining the next targets. The HFMM uses these five levels: Emerging, Transitional, Planned, Proactive and Leading. The model includes 12 specific elements of human factors, which are assessed separately using the maturity levels [10,11,12]:

1.Managing Human Failure (including maintenance
2.Human Factors in Incident Investigation
3.Design and Development of Procedures
4.Training and Competence
5.Staffing and Workload
6.Managing Organizational Change

Table 1 : Overview of safety culture maturity model

Model	Levels	Key elements
Safety Culture Maturity Model-Fleming (2000)	Emerging Managing Involving Co-operating Continually Improving	Management commitment and visibility- Communication Productivity versus safety- Learning organisation Safety resources- Participation Shared perceptions about safety- Trust Industrial relations and job satisfaction- Training
Cultural Maturity Model- Fleming & Meakin (2004)	Documenting Controlling Engaging Participating Institutionalizing	Visibility of management commitment- Supervisor visible comitment Production pressures- Organizational learning Job and safety communication- Human and physical resources Rules and procedures-Trust levels Training- Workforce involvement
Safety Culture Survey-Gordon (2007)	Emerging Managing Involving Proactive Continually Improving	Management Commitment to Safety- Safety Performance Goals Impact- Investment & Resource Allocation Policy & Strategy on Safety- Safety versus Productivity Safety Planning- Training & Competence Knowledge of ATM Risks- Risk Assessment & Management Communication-Integrated Teams- Involvement of Employees Relationship w/ External Regulator- Involvement of Stakeholders Trust & Confidence- Responsibility for Safety Organizational Learning- Safety Management System / Audit Achievement of Safety Targets- Test of safety in design
UK Coal Maturity Model-Foster & Hoult (2013)	Basic Reactive Planned Proactive Resilient	Leadership & Accountability- Policy & Commitment Risk & Change Management- Legal Requirements Objectives, Targets & Performance Measurement Training, Competence & Awareness Communication & Consultation Control of Documents - Operational Controls Emergency Procedures- Incident Investigation Monitoring, Auditing & Reviews

7.Safety-Critical Communications
8.Human Factors in Design
9.Fatigue and Shift work
10.Safety Culture and Behaviour
11.Contractor Management
12.Managing Performance under Pressure.

The problem with existing maturity models is that the proposed methodologies for measuring maturity do not consider the uncertainty and vagueness of human decisions, as well as the interdependencies between factors. In fact, in this work, it is proposed to assess the HOF maturity using the Fuzzy ANP with an extent analysis approach to address this issue.

3. STRUCTURE OF THE MATURITY MODEL

The maturity model proposed in this work, is based on six key elements (Factors): Organizational Policy, Planning, Implementing, Measuring, Checking and Assurance, Auditing and Reviewing. Each element contains its associated characteristics (Sub-factors) related to HOF issues, which are described below (Figure 1). [9,10]

To give an easy-to-apply model and help decision-makers when assessing the HOF sub-factors, we have listed for each characteristic its related HOF questions (Tables 2, 3, 4, 4, 6, 7).

Table 2 : Key questions of "Organizational Policy" sub-factors

HOF characteristics	Key Questions
HOF Policy & Strategy (OP1)	Documented and accessible HOFs' Policy. Monitoring the HOFs policy and strategy is an integral part of the company's processes and culture. Safety vs. Production. Safety department size and status.
Recognition (OP2)	The organization looks at the role of the human in the operation or maintenance of equipment or installations, or the impact of these on the users
Leadership & Responsibility (OP3)	Adoption of Safety management. Leadership and commitment to safety. Prize for good safety performance.
User & Contractor Involvement (OP4)	Inclusion of requirements related to HOFs in the contractual documentation. Produce HOFs program plans.

Table 3 : Key questions of "Planning" sub-factors

HOF characteristics	Key Questions
Targets & Measurement Methodology (P1)	Targets setting. Definition of the measurement methodology.
Training & Competence (P2)	Competence evaluation. Training planning. Training appraisal.
Human Factors Planning (P3)	Inclusion of relevant tasks in project plans. Existence of a Human Factors / Ergonomics management plan.
Human Factors in Design (P4)	Equipment design meets human needs. Ergonomic design.
Managing Human Error (P5)	Consideration of human error in design and implementation. Make efforts to avoid error, improve detection, or mitigate consequences if it occurs.
Risk Management (P6)	Management of Major Risks. Work safety analysis.
Organizational Change (P7)	Treat and anticipate the perspective of human factors during the planning of any organizational change. The full participation of all the personnel concerned must take place as soon as possible, preferably well before the introduction of any change.
Emergency Procedures (P8)	Emergency planning standard. Methodology to maintain and monitor the response.

Table 4 : Key questions of "Implementing" sub-factors

HOF characteristics	Key Questions
Operational Control (I1)	Daily Inspections. Control of compliance with work planning and procedures. Maintenance and corrective actions.
Document Control (I2)	Compliance with applicable documents. Update documents. Accessible and easily identifiable documents.
Communication (I4)	Define safety critical communication requirements. Access to essential safety information.

Table 5 : Key questions of "Measuring" sub-factors

HOF characteristics	Key Questions
Performance Measurement / Targets (M1)	Measure safety performance and compare with defined targets Periodic update of indicators
Operability Validation (M2)	Conduct appropriate design testing activities to validate operations or maintenance tasks where humans have a potentially critical role, or which may expose operators to hazards or stress

Table 6 : Key questions of "Checking & Assurance" sub-factors

HOF characteristics	Key Questions
Incident Investigation (CA1)	Accident investigation. Surveys quality. Monitoring and analysis.
HOFs in Incident Investigation (CA2)	Consider the HOFs issues during the investigation.

Table 7 : Key questions of "Auditing & Reviewing" sub-factors

HOF characteristics	Key Questions
Auditing / Standards (AR1)	Periodic auditing to compare with HOFs standards. Update of HOFs procedures.
Lessons Learned (AR2)	Learn lessons from events (incidents, accidents, procedural deviations…) that had or could have had an impact on safety are regularly documented and fed back to improve HOFs procedures throughout the organization.

To determine the HOF maturity, we suggest using the levels presented in Figure 2. [13]

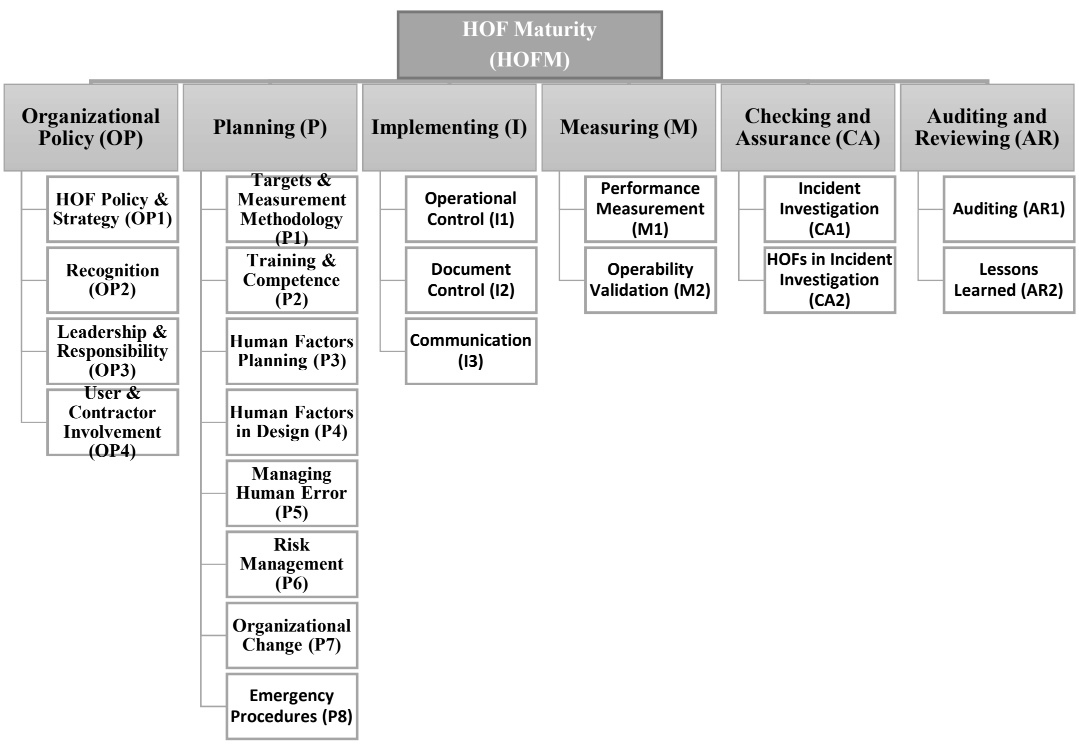

Figure 1: The HOF maturity model

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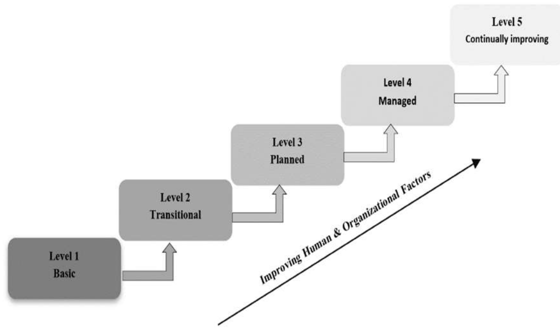

Figure 2 : The HOF maturity levels

4. FUZZY ANP METHOD

To assess the maturity level using the proposed model, we propose the use of the FANP for two reasons: First, the ANP is a generalization of the Analytic Hierarchy Process introduced by Saaty, and it considers the interdependence between the hierarchy's elements [14, 15]. Second, the human judgement is vague and difficult to estimate by exact values, so it is recommended to use the fuzzy logic which deals with complex problems characterized by imprecision and vagueness [16].

To determine the maturity level employing the FANP method with the extent analysis approach, the steps to follow are presented below [17, 18]:

1) Construct the ANP hierarchical model by identifying the goal, factors, and sub-factors.

2) Produce the pairwise comparison matrices of factors and sub-factors to calculate the local weights, with the assumption that there is no dependency between the factors. The fuzzy scale used for determining the relative importance of elements is given in Table 8 [19].

Table 8 . Linguistic scale for importance

Linguistic scale for relative importance	Triangular Fuzzy Scale
Just Equal	(1, 1, 1)
Equally Important	(1/2, 1, 3/2)
Weakly more important	(1, 3/2, 2)
Strongly more important	(3/2, 2, 5/2)
Very strongly more important	(2, 5/2, 3)
Absolutely more important	(5/2, 3, 7/2)

3) Calculate the inner dependence matrix by analyzing the impact of each factor on the others. Then, to determine the factors' interdependent weights, the inner dependence matrix is multiplied with the local weights.

4) Compute the sub-factors' global weights, by multiplying the sub-factor's local weight with its related factor's interdependent weight.

5) Assess the sub-factors utilizing the linguistic variables given by Cheng [20]. The average values of these variables are presented in Table 9, and the membership functions are shown in Figure 3.

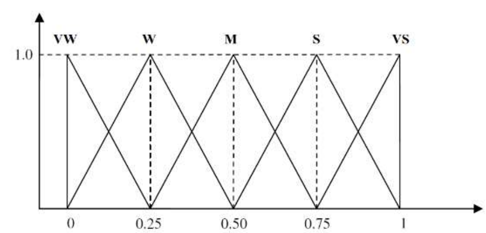

Figure 3: Membersip functions of linguistic values

Table 9 . Linguistic values for sub-factors' rating

Linguistic values	The mean of fuzzy numbers
Very Strong (VS)	1
Strong (S)	0.75
Medium (M)	0.5
Weak (W)	0.25
Very Weak (VW)	0

6) Calculate the Maturity Level (ML) by using the sub-factors' global weights and the mean of fuzzy numbers. According to the ML value obtained, the HOF maturity level (HOFML) is determined:

- ✓ $ML \leq 0.2$, the HOFML is Basic.
- ✓ $0.2 < ML \leq 0.4$, the HOFML is Transitional.
- ✓ $0.4 < ML \leq 0.6$, the HOFML is Planned.
- ✓ $0.6 < ML \leq 0.8$, the HOFLML is Managed.
- ✓ $0.8 < ML \leq 1$, the HOFML is Continually Improving.

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5. *CASE STUDY*

5.1 Numeric Application

The HOF maturity model suggested in this paper is applied in a Moroccan cement plant. After carrying out a deep analysis of workplace incidents, the company found that 80% of the causes are related to human and organizational factors. Therefore, for reducing the incidents, and improving the human performance, the company decided to measure its own HOF maturity through the proposed model. Thus, a managers group was selected from different departments (Production, Safety, Maintenance, Quality and Environment, Logistics and Optimization), to carry out the pairwise comparisons and assess the maturity of sub-factors. The steps followed in this case study are presented below:

1) Construct the ANP hierarchical model : The model used in this step is the one proposed in the section " Structure of the maturity model" .(Figure 1)

2) Calculate the local weights of factors and sub-factors : The pairwise comparisons performed by the managers are shown in Tables 9, 10, 11, 12, 13, 14, 15 .

Local weights are computed using Chang's extent analysis method [21, 22]. As an example, from Table 9 , the weights of factors are determined as follows:

Table 9 . Comparison matrix and local weights of factors

HOFM	OP	P	I	M	CA	AR	Weights
OP	(1, 1,1)	[illegible]	[illegible]	[illegible]	[illegible]	(5/2, 3, 7/2)	**0.30**
P	(1/3, 2/5, 1/[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(1/2, 1, 3/2)	**0.10**
I	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 3/2, 2)	**0.17**
M	(2/3, 1, 2)	(1, 3/2, 2)	(1, 3/2, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	**0.21**
CA	(1/2, 2/3, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(2/3, 1, 2)	(1, 1, 1)	(1, 1, 1)	**0.16**
AR	(2/7, 1/3, 2/5)	(2/3, 1, 2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1, 1, 1)	**0.07**

a) S_{OP}= (8.50, 11.00, 13.50) ⊗(1/54.73, 1/39.90, 1/29.92) = (0.16, 0.28, 0.45)
S_P= (3.50, 4.73, 7.00) ⊗ (1/54.73, 1/39.90, 1/29.92) = (0.06, 0.12, 0.23)
S_I= (4.23, 6.00, 9.17) ⊗ (1/54.73, 1/39.90, 1/29.92) = (0.08, 0.15, 0.31)
S_M= (5.17, 7.50, 10.50) ⊗ (1/54.73, 1/39.90, 1/29.92) = (0.09, 0.19, 0.35)
S_{CA}= (4.67, 6.17, 8.50) ⊗ (1/54.73, 1/39.90, 1/29.92) = (0.09, 0.15, 0.28)
S_{AR}= (3.85, 4.50, 6.07) ⊗ (1/54.73, 1/39.90, 1/29.92) = (0.07, 0.11, 0.20)

b) V ($S_{OP} \geq S_P$) = 1; V ($S_{OP} \geq S_I$) = 1; V ($S_{OP} \geq S_M$) = 1; V ($S_{OP} \geq S_{CA}$) = 1; V ($S_{OP} \geq S_{AR}$) = 1.

V ($S_P \geq S_{OP}$) = 0.33; V ($S_P \geq S_M$) = 0.83 ; V ($S_{OP} \geq S_I$) = 0.67; V ($S_P \geq S_{CA}$) = 0.81; V ($S_P \geq S_{AR}$) = 1 .

V ($S_I \geq S_{OP}$) = 0.55; V ($S_I \geq S_P$) = 1 ; V ($S_I \geq S_M$) = 0.85; V ($S_I \geq S_{CA}$) = 0.98; V ($S_I \geq S_{AR}$) = 1.

V ($S_M \geq S_{OP}$) = 0.69; V ($S_M \geq S_P$) = 1 ; V ($S_M \geq S_I$) = 1 ; V ($S_M \geq S_{CA}$) = 1 ; V ($S_M \geq S_{AR}$) = 1.

V ($S_{CA} \geq S_{OP}$) = 0.52; V ($S_{CA} \geq S_P$) = 1 ; V ($S_{CA} \geq S_I$) = 1 ; V ($S_{CA} \geq S_M$) =0.85 ; V ($S_{CA} \geq S_{AR}$) = 1.

V ($S_{AR} \geq S_{OP}$) = 0.23; V ($S_{AR} \geq S_P$) = 0.96; V ($S_{AR} \geq S_I$) = 0.77; V ($S_{AR} \geq S_M$) = 0.59; V ($S_{AR} \geq S_{CA}$) =0.74.

c) d'(A_{OP}) = V ($S_{OP} \geq S_P, S_I, S_M, S_{CA}, S_{AR}$) = 1 ;
d'(A_P) = V ($S_P \geq S_{OP}, S_I, S_M, S_{CA}, S_{AR}$) = 0.33 ;
d'(A_I) = V ($S_I \geq S_{OP}, S_{OP}, S_M, S_{CA}, S_{AR}$) = 0.55 ;
d'(A_M) = V ($S_M \geq S_{OP}, S_P, S_I, S_{CA}, S_{AR}$) = 0.69 ;
d'(A_{CA}) = V ($S_{CA} \geq S_{OP}, S_P, S_I, S_M, S_{AR}$) =0.52 ;
d'(A_{AR}) = V ($S_{AR} \geq S_{OP}, S_P, S_I, S_M, S_{CA}$) =0.23 .

d) Then, the local weight vector is obtained as:

$$W = (d'(A_{OP}), \dots, d'(A_{AR}))^T = (0.30, 0.10, 0.17, 0.21, 0.16, 0.07).$$

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The sub-factors' local weights are obtained using the same steps of Chang's extent analysis method.

3) By considering the interdependencies between the factors, the relative importance (RI) weights are calculated using the dependence matrices presented in Tables 16, 17, 18, 19, 20, 21 .

The factors' interdependent weights are computed by multiplying the dependence matrix composed of relative importance weights, with the factors' local weights:

$$\begin{bmatrix} 1 & 0.32 & 0.50 & 0.13 & 0.24 & 0.31 \\ 0.07 & 1 & 0.26 & 0.24 & 0.15 & 0.18 \\ 0.12 & 0.15 & 1 & 0.31 & 0.21 & 0.11 \\ 0.18 & 0.20 & 0.07 & 1 & 0.34 & 0.18 \\ 0.24 & 0.19 & 0.15 & 0.15 & 1 & 0.23 \\ 0.40 & 0.14 & 0.03 & 0.17 & 0.07 & 1 \end{bmatrix} \times \begin{bmatrix} 0.30 \\ 0.10 \\ 0.17 \\ 0.21 \\ 0.16 \\ 0.07 \end{bmatrix}$$

$$= (0.50 \quad 0.24 \quad 0.33 \quad 0.36 \quad 0.32 \quad 0.26)$$

After normalizing the vector, the interdependent weights are given as follows:

W = (0.25, 0.12, 0.16, 0.18, 0.16, 0.13)

4) Calculate the global weights of the sub-factors: The results are shown in Table 22.

5) Assess the sub-factors by the managers group using Cheng's linguistic variables (Table 9). The assessments obtained are presented in Table 22.

6) Calculate the Maturity level using the results shown in Table 22 as following :

$$ML = \sum GW \text{ x } MV = 0.576$$

Table 10 . Comparison matrix and local weights of Organizational Policy sub-factors

OP	OP1	OP2	OP3	OP4	Weights
OP1	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	**0.33**
OP2	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	**0.22**
OP3	(2/3, 1, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)	**0.25**
OP4	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	**0.20**

Table 11 . Comparison matrix and local weights of Planning sub-factors

P	P1	P2	P3	P4	P5	P6	P7	P8	Weights
P1	(1, 1, 1)	(2/5, 2, 2/3)	(1/3, 2/5, 1/2)	(1/3, 2/5, 1/2)	(1/2,1,3/2)	(1/2,1,3/2)	(3/2,2,5/2)	(3/2,2,5/2)	**0.12**
P2	(3/2,1/2, 5/2)	(1, 1, 1)	(1/2, 1, 3/2)	(1,3/2, 2)	(2, 5/2, 3)	(3/2,2,5/2)	(5/2,3,7/2)	(5/2,3,7/2)	**0.23**
P3	(2,5/2,3)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(1, 3/2, 2)	(3/2,2,5/2)	(2,5/2,3)	(2, 5/2, 3)	**0.22**
P4	(2, 5/2, 3)	(1/2, 2/3, 1)	(2/3, 1, 2)	(1, 1, 1)	(1, 3/2, 2)	(1/2,1,3/2)	(1, 3/2, 2)	(1, 3/2, 2)	**0.16**
P5	(2/3,1, 2)	(1/3, 2/5, 1/2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1,3/2,2)	(1/2,1,3/2)	**0.08**
P6	(2/3,1, 2)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(2/3,1, 2)	(1/2,1,3/2)	(1, 1, 1)	(1/2,1,3/2)	(1/2,1,3/2)	**0.09**
P7	(2/5,1/2, 2/3)	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	(2/3, 1,2)	**0.05**
P8	(2/5,1/2, 2/3)	(2/7, 1/3, 2/5)	(1/3, 2/5, 1/2)	(1/2,2/3, 1)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)	(1, 1, 1)	**0.06**

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I	I1	I2	I3	Weights
I1	(1, 1, 1)	(1, 3/2, 2)	(2/3, 1, 2)	0.38
I2	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)	0.24
I3	(1/2, 1, 3/2)	(1, 3/2, 2)	(1, 1, 1)	0.38

Table 12 : Comparison matrix and local weights of Implementing sub-factors

M	M1	I2	Weights
M1	(1, 1, 1)	(1, 3/2, 2)	0.68
M2	(1/2, 2/3, 1)	(1, 1, 1)	0.32

Table 13: Comparison matrix and local weights of Measuring sub-factors

CA	CA1	CA2	Weights
CA1	(1, 1, 1)	(1/2, 1, 3/2)	0.50
CA2	(2/3, 3, 2)	(1, 1, 1)	0.50

Table 14 : Comparison matrix and local weights of Checking & Assurance sub-factors

AR	AR1	AR2	Weights
AR1	(1, 1, 1)	(1/2, 1, 3/2)	0.50
AR2	(2/3, 3, 2)	(1, 1, 1)	0.50

Table 15 : Comparison matrix and local weights of Checking & Assurance sub-factors

Table 16 : Inner dependence matrix of factors with respect to " OP"

OP	P	I	M	CA	AR	RI Weights
P						
I						
M	(1, 3/2, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	0.18
CA	(3/2, 2, 5/2)	(1, 3/2, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 2/3, 1)	0.24
AR	(2, 5/2, 3)	(2, 5/2, 3)	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)	0.40

Table 17 : Inner dependence matrix of factors with respect to " P"

P	OP	I	M	CA	AR	RI Weights
OP	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(3/2, 2, 5/2)	(3/2, 2, 5/2)	0.32
I	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)	(2/3, 1, 2)	(1, 1, 1)	0.15
M	(1/2, 2/3, 1)	(1, 3/2, 2)	(1, 1, 1)	(1/2, 2/3, 1)	(1, 3/2, 2)	0.20
CA	(2/5, 1/2, 2/3)	(1/2, 1, 3/2)	(1, 3/2, 2)	(1, 1, 1)	(1/2, 1, 3/2)	0.19
AR	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)	0.14

Table 18 : Inner dependence matrix of factors with respect to " I"

I	OP	P	M	CA	AR	RI Weights
OP	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	0.50
P	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	0.26
M	(1/3, 2/5, 1/2)	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	0.07
CA	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)	0.15
AR	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	0.03

Table 19 : Inner dependence matrix of factors with respect to " M"

M	OP	P	I	CA	AR	RI Weights
OP	(1, 1, 1)	(1/2, 2/3, 1)	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(1, 1, 1)	0.13
P	(1, 3/2, 2)	(1, 1, 1)	(2/3, 1, 2)	(1, 3/2, 2)	(1/2, 1, 3/2)	0.24
I	(2, 5/2, 3)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 3/2, 2)	(3/2, 2, 5/2)	0.31
CA	(1/2, 1, 3/2)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 1, 3/2)	0.15
AR	(1, 1, 1)	(2/3, 1, 2)	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(1, 1, 1)	0.17

Table 20 : Inner dependence matrix of factors with respect to " CA"

CA	OP	P	I	M	AR	RI Weights
OP	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(2/3, 1, 2)	(1, 3/2, 2)	0.24
P	(2/3, 1, 2)	(1, 1, 1)	(1, 1, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	0.15
I	(2/3, 1, 2)	(1, 1, 1)	(1, 1, 1)	(1/2, 2/3, 1)	(1, 3/2, 2)	0.21
M	(1/2, 1, 3/2)	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)	(2, 5/2, 3)	0.34
AR	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)	(1/3, 2/5, 1/2)	(1, 1, 1)	0.07

Table 21 : Inner dependence matrix of factors with respect to " AR"

AR	OP	P	I	M	CA	RI Weights
OP	(1, 1, 1)	(3/2, 2, 5/2)	(2, 5/2, 3)	(1, 3/2, 2)	(1/2, 1, 3/2)	0.31
P	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/2, 1, 3/2)	(2/3, 1, 2)	(2/3, 1, 2)	0.18
I	(1/3, 2/5, 1/2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	0.11
M	(1/2, 2/3, 1)	(1/2, 1, 3/2)	(1, 3/2, 2)	(1, 1, 1)	(1, 1, 1)	0.18
CA	(2/3, 1, 2)	(1/2, 1, 3/2)	(3/2, 2, 5/2)	(1, 1, 1)	(1, 1, 1)	0.23

Table 22 : The Maturity level using the proposed model and the Fuzzy ANP method

Factors	Sub-factors	Local Weights	Global Weights (GW)	Linguistic Variable	Mean Value (MV)	GWxMV
Organizational Policy (0.25)	HOF Policy & Strategy	0.33	0.08	S	0.75	0.062
	Recognition	0.22	0.06	W	0.25	0.014
	Leadership & Responsibility	0.25	0.06	M	0.50	0.031
	User & Contractor Involvement	0.20	0.05	S	0.75	0.038
Planning (0.12)	Targets & Measurement Methodology	0.12	0.01	M	0.50	0.007
	Training & Competence	0.23	0.03	S	0.75	0.020
	Human Factors Planning	0.22	0.03	W	0.25	0.007
	Human Factors in Design	0.16	0.02	M	0.50	0.010
	Managing Human Error	0.08	0.01	W	0.25	0.002
	Risk Management	0.09	0.01	S	0.75	0.008
	Organizational Change	0.05	0.01	W	0.25	0.001
	Emergency Procedures	0.06	0.01	S	0.75	0.005
Implementing (0.16)	Operational Control	0.38	0.06	S	0.75	0.046
	Document Control	0.24	0.04	S	0.75	0.029
	Communication	0.38	0.06	M	0.50	0.030
Measuring (0.18)	Performance Measurement	0.68	0.12	S	0.75	0.092
	Operability Validation	0.32	0.06	M	0.50	0.029
Checking & Assurance (0.16)	Incident Investigation	0.50	0.08	S	0.75	0.060
	HOF in Incident Investigation	0.50	0.08	W	0.25	0.020
Auditing & Reviewing (0.13)	Auditing	0.50	0.07	S	0.75	0.049
	Lessons Learned	0.50	0.07	W	0.25	0.016
						ML = ∑ GW x MV = 0.576

5.2 Discussion

According to the value of the ML obtained ($0.4 < 0.576 \leq 0.6$), the HOFML of the cement plant is “Planned”. Therefore, depending on the results, the company is closed to achieve the level “Managed”. Thus, it is agreed to start by increasing efforts on these characteristics: “Lessons Learned”, “ HOF in Incident Investigation”, “Recognition”, “Communication”, “Leadership & Responsibility” and “Operability Validation” seen their significant weightings. Then, despite the minor weights of the following sub-factors: “Human Factors Planning”, “Human Factors Planning” and “Organizational Change” , the organization decided to improve them, since they have a weak maturity level.

All the agreed improvement decisions are planned through an action plan, which contains the characteristics to be enhanced and the steps to be followed. The company has taken into account the key questions related to the HOF sub-factors (Tables 2-7) to guide them during the development of the action plan.

Unlike the maturity measurement methods presented in the literature review, the FANP method used in this case study enabled the company to take into account the interdependencies between the various factors and deal with the fuzziness and imprecision of human judgments.

6. CONCLUSION

Organizations operating in different sectors are increasingly aware of the impact of human and organizational factors in the achievement of a successful human performance. This recent emphasis on maturity models offers companies wishing to improve their actual situation the opportunity to determine their degree of maturity and identify how to achieve an effective HOF management.

The HOF maturity model presented in this paper is made up of six elements: Organizational Policy, Planning, Implementing, Measuring, Checking & Assurance and Auditing & Reviewing. For each factor is listed a set of HOF characteristics described with their related key questions . Then, to determine the HOF maturity level among the five presented in the Figure 2, it is suggested to use the Fuzzy ANP method to consider the interdependencies between the factors and the vagueness of the human decisions.

The proposed HOF model and methodology are applied in a cement plant to determine the actual maturity level, and improvement areas. To validate their effectiveness in determining the real situation of the company, it is suggested to measure the maturity again after improving the characteristics defined in the action plan, and check if the company will reach the next maturity level. The model can also be used in other industries to test whether it really reflects the current state of companies in terms of HOF.

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