ASSESSMENT AND IMPROVEMENT OF HUMAN AND ORGANIZATIONAL FACTORS IN AN AUTO-PARTS MANUFACTURING PLANT USING THE FUZZY ANALYTICAL NETWORK PROCESS COMBINED WITH THE FUZZY COMPREHENSIVE EVALUATION METHOD

YOUSRA KARIM [1] , ABDELGHANI CHERKAOUI[2]

Research Team EMISYS: Energetic, Mechanic and Industrial Systems,

Engineering 3S Research Center, Industrial Engineering Department,

Mohammadia School of Engineers, Mohammed V University, Rabat, Morocco.

E-mail: yousrakarim@research.emi.ac.ma

ABSTRACT

Nowadays, the highly competitive intensity pushes manufacturing companies to continuously improve the production process, by applying a variety of tools and strategies that can help identify the reduction or elimination of waste, lower the product cost and minimize the product manufacturing time. Taking into account human and organizational factors (HOF) can also lead the factory to significant productivity gains by positively affecting human performance and thus reduce the risk of accidents at work. Maturity models can therefore be used as continuous improvement tools by assessing the maturity of HOF first, then determine the elements to be enhanced to reach a high level of maturity. In this article, a study is conducted in a multinational auto-parts manufacturing plant using an HOF maturity model (HOFMM) and the combination of two methods: Fuzzy Analytical Network Process (FANP) and Fuzzy Comprehensive Evaluation Method (FCEM), which allow to consider the relations between the factors as well as the inaccuracy and fuzziness of the decisions taken by the human being.

Keywords: *Safety, Human and Organizational Factors, Maturity, Fuzzy Analytical Network Process, Fuzzy Comprehensive Evaluation Method.*

1. INTRODUCTION

Occupational safety is a multidisciplinary approach which aims to eliminate or reduce the risk of accidents likely to occur during the exercise of a professional activity [1]. Figure 1 shows the evolution over time of the successive methods developed and used to reduce the rate of accidents at work.

Developed since the 2000s, the HOF approach aims to better understand the human activity, and to act on the design of work situations and organization in order to create the necessary conditions for a safe activity.

Over the past thirty years, an expertise in industrial safety has been developed in the field of HOF, based on human and social sciences. It is accompanied by a set of approaches (knowledge, practices and data collection techniques) that are potentially available to companies. Thus, there is an abundant literature on the subject with numerous methods (work observation, interview and questioning techniques, questionnaires…).

The diversity of approaches is today an obstacle for companies wishing to analyze and strengthen their HOF practices. Hence the usefulness of the maturity model concept, which provides a framework for companies during the assessment and improvement process.

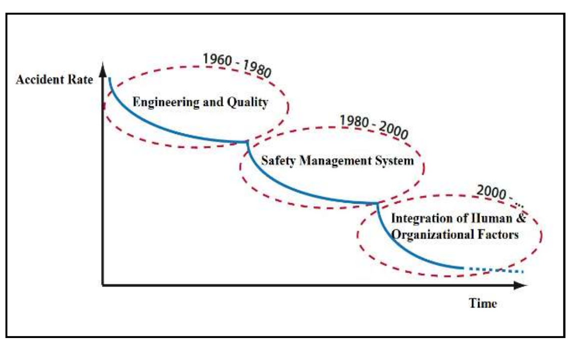

Figure 1: Successive approaches to occupational safety

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The maturity model presented in this article is composed of five main elements related to HOF, which allow to guarantee a better safety at work and also have a high human performance. Using the combination of the two methods Fuzzy Analytic Network Process (FANP) and FCEM, the overall maturity level is determined as well as the level of the five factors. Which then makes it possible to define the weaknesses and strengths relating to HOF. This model is not intended for a specific industry, but it can be applied by any company as the elements are essential for safety and performance in all sectors.

The automotive industry is one of the most important manufacturing sectors, with a considerable economic weight and is subject to strong competition. The high production rates of the workers tend to increase the frequency of work accidents. In addition, the required productivity gains exert a constant pressure on the working conditions of staff in all departments, which causes the appearance of frequent psychosocial disorders.

Different industrial management methods are used in this sector, especially the "Lean Manufacturing" originally developed in the Toyota Production System (TPS), which is based on eliminating waste within production processes [2]. However, increasing productivity by reducing costs and deadlines can also deteriorate working conditions and create stressful situations if it is poorly implemented, applied in a directive manner or through abrupt change.

Therefore, the maturity model described in this work is utilized in an auto-parts manufacturing plant to assess the maturity and check if the management methods used have negatively impacted the crucial HOF such as the working conditions.

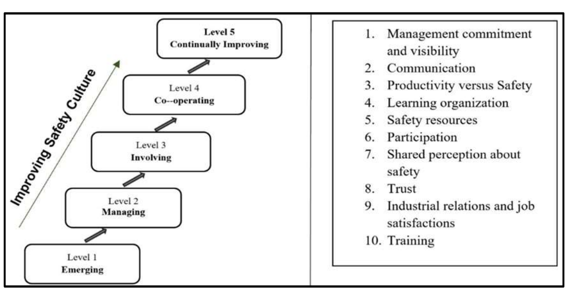

Figure 2: Safety Culture Maturity Model

2. LITERATURE REVIEW

2.1 Maturity Models

Since the development of the Capability Maturity Model [3] which was based on the Quality Management Grid [4] and Westrum's Typology of Organizational Cultures [5], a growing number of maturity models have been proposed by researchers in different sectors. These models are used by companies to assess the current performance in a specific area, and identify the strengths and weaknesses related to the characteristics of the model.

There are many maturity models related to safety and human factors like: Safety Culture Maturity Model (SCMM) [6], Hudson Maturity Model [5], Anglo American Plc Maturity Model, UK Coal Maturity Model [7] …

Each model defines a number of maturity levels, and proposes a set of key elements related to safety or human factors through which the maturity level can be measured. An example of the SCMM developed by Fleming, which suggested the five levels of maturity, and the ten elements related to safety presented in Figure 2.

To determine the level of maturity, each model proposes its own measurement methodology. The most commonly used is to ask the group of model and assign it to one of the predefined maturity levels, such as the card sorting methodology proposed in the Human Factors Maturity Model (HFMM) [8].

After analyzing the different maturity models proposed and the evaluation methodologies, it can be seen that the concept is similar to a multi-criteria decision-making problem (MCDM). Thus, a literature review of MCDM methods is carried out in order to choose the most suitable method to assess the maturity level.

2.2 MCDM Methods

The MCDM focuses on structuring and solving decision and planning problems involving multiple criteria and alternatives. The goal is to support decision makers facing such problems. Typically, there is no single optimal solution for such problems and it is necessary to use the decision maker's preferences to differentiate solutions [9].

The multi-criteria decision methods aim to provide a decision maker with the tools allowing him to progress in the resolution of the decision problem where several points of view, often contradictory, must be taken into account [10].

These methods are developed to deal with different decision issues (choice, sorting, description and storage, etc.) while taking into account a set of criteria (attributes), often conflicting and non-

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commensurable and seeking to best model the preferences and values of the decision-maker (s) [11].

There are several categorizations of these MCDM problems. Farahani et al divide the problem into a combination of two families: the multi-attribute decision and the multi-objective decision [12].

2.2.1. Multi-objective decision methods:

Multi-objective decision methods aim at finding the best alternative by considering the different interactions between the constraints of the problem. This alternative is the one that best satisfies all the objectives.

The methods belonging to this family of multi-objective decision support have various characteristics, the common features are as follow: a set of quantifiable objectives and a set of well-defined constraints.

The methods proposed to solve multi-objective decision support problems are numerous in the literature. As an example, we cite Goal Programming (GP), the Lexicographic method, metric L-P methods, method of Geoffrion … [13, 14]

2.2.2. Multi-attribute decision methods:

In this family of methods, the problem to be dealt with usually involves a limited number of predetermined alternatives. These alternatives satisfy each objective to a certain level. The decision maker chooses the best solution (s) from among all the alternatives depending on the priority of each objective and the interaction between them.

There are several methods to solve decision problems multi-attribute such as: Analytic Hierarchical Process (AHP), Analytic Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELimination Et Choix Traduisant la REalité (ELECTRE)…

- AHP: A structured method developed by Saaty in 1970, based on psychology and mathematics. It has the capacity to manage different classes of qualitative and quantitative criteria. The application of this method is done at two levels: First the hierarchical structure of the problem and then the evaluation through comparison matrices [15].
- ANP: This is a general case of the AHP method, because it considers the relationship between criteria which gives reliable results [16].
- TOPSIS: A multi-criteria decision technique for ranking and selecting among a number of alternatives via Euclidean distance, developed by Hwang and Yoon in 1981[17]. Its principle consists in determining for each alternative a coefficient between 0 and 1 on the basis of the distances between each alternative and the favorable and unfavorable ideal solutions.

  An alternative is called ideal favorable if it is the farthest from the worst alternative and the closest to the best alternative.

  An alternative is called unfavorable ideal if it is the closest to the worst alternative and the farthest from the best alternative.
- Outranking Methods: This family of methods is developed in Europe in 1960s, which consists in ensuring the comparison of the alternatives in pairs using an outranking relation S [18].

S is a binary relation on the set of the alternatives A. In principle, an alternative a is at least as good as alternative b (a S b) if a is at least as good as b on a majority of criteria (concordance condition) without being significantly worse on the other criteria (non-discordance condition).

Among the outranking methods, there is the simplest and oldest ELECTRE I developed by Roy in 1968, followed by the ELECTRE family methods (ELECTRE II, ELECTRE III, ELECTRE IV and ELECTRE TRI) [19].

In many multi-attribute problems, the data collected is inaccurate and vague because decisions are based on human reasoning which lacks certainty. Hence the idea of combining fuzzy logic introduced by Zadeh in 1965 [20], with the above-mentioned methods (Fuzzy TOPSIS, Fuzzy AHP…) to solve problems with greater reliability and precision.

3. HUMAN AND ORGANIZATIONAL FACTORS MATURITY MODEL DESCRIPTION

We have proposed two different maturity models in previous publications; the first model (M1) is made up of the five key elements that are crucial for a safe human performance [21, 22] and the second model (M2) is based on a literature review of existing models related to safety and human factors [23]. The elements that we used in the two different models to measure the maturity related to HOF are presented in Table 1.

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Table 1: Key Elements of M1 & M2

Key Elements of M1	Key Elements of M2
Design (F1) Staffing (F2) Training (F3) Culture (F4) Conditions (F5)	Organizational Policy (OP) Planning (P) Implementing (I) Measuring (M) Checking and Assurance (CA) Auditing and Reviewing (AR)

It can be directly noticed that the characteristics of M2 are included in each factor of model 1, seen that these elements of M2 can be considered as the six steps necessary to improve each of the five key factors, starting by including it in the organizational policy (OP) of the company, next planning (P) and implementing (I) appropriate procedures, then measuring the progress (M), finally checking (CA) and auditing (AR).

In addition, it can be seen that model 1 reflect the state of real work situation, therefore the results obtained are close to reality. therefore model 1 represents a more general framework for measuring the level of maturity of human and organizational factors.

In addition, it can be seen that model 1 reflects the state of the real work situation, so the results obtained are close to reality. This model therefore represents a more general framework for measuring the maturity level of human and organizational factors.

The model 1 that we have decided to name Human and Organizational Factors Maturity Model (HOFMM) is made up of the five factors listed in the guide "Understanding Human Factors" established by the Rail and Safety Standard Boards (RSSB), which aimed to help railway industry companies ensure that employees have safe and easy-to-use equipment and a place where they can work efficiently [24].

The five factors proposed in the guide, which constitute the main elements of our model (Figure 3), are essential for effective and safe human performance not only in the railway industry but in all high-risk sectors like the mining and construction industries.

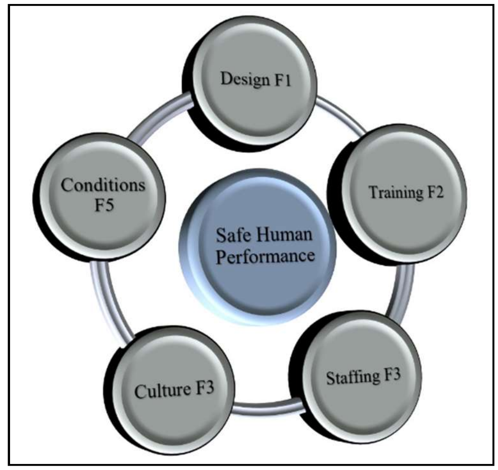

Figure 3: Key Factors of HOFMM

To measure the maturity level that represents the degree of integration of HOF in the company, a five-level scale (Figure 4) is used to evaluate each factor and then find the overall level.

The following tables present the main factors and sub-factors of the HOFMM with related key questions that make the model understandable and easy to manipulate by companies.

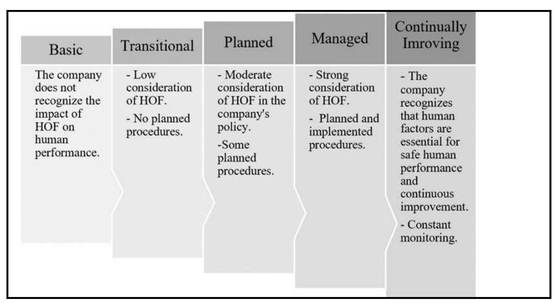

Figure 4: Maturity Levels of HOFMM

Table 2: Sub-factors and key questions of Design

	Sub-factors	Key Questions
Design F1	1. Equipment Design F11 2. Workplace Design F12 3. Job Design F13	1. Is the design of the equipment meet user needs (visibility, workflow, constraints, environment, workload, etc.)? 2. How do you assess the design of the workplace? 3. How do you perceive the job design (job descriptions) produced by the company?

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Table 3: Sub-factors and key questions of Training

	Sub-factors	Key Questions
Training F2	1. Effective Training Program F21 2. Training Appraisal F22	1. How do you rate the effectiveness of the training programs? 2. How do you perceive the process of assessing the trainings carried out by the company (reaction of trainees, learning objectives…)?

Table 4: Sub-factors and key questions of Staffing

	Sub-factors	Key Questions
Staffing F3	1. Recruitment F31 2. Retention F32	1. How do you perceive the selection and recruitment process? 2. How do you find the efforts made by the company to keep the people recruited?

Table 5: Sub-factors and key questions of Culture

	Sub-factors	Key Questions
Culture F4	1. Leadership F41 2. Management F42 3. Teamworking F43 4. Communication F44 5. Change F45	1. How do you rate the involvement of managers and leaders in the HOFs procedures? 2. How do you perceive the supervision of teamwork within your company? 3. How do you rate the quality of communication? 4. How do you perceive the involvement and commitment of employees in change projects?

Table 6: Sub-factors and key questions of Culture

	Sub-factors	Key Questions
Conditions F5	1. Morale & Motivation F51 2. Stress F52 3. Workload F53 4. Shift work F54	1. How would you rate the practices put in place by the company to improve morale and motivate employees at work? 2. How do you see the strategy adopted by the company to manage stress? 3. How do you perceive the workload? 4. How do you perceive the work shift planning?

4. MEASUREMENT METHODS

The HOFMM was first implemented in a company operating in the construction industry using a combination of the AHP and Fuzzy Comprehensive Evaluation Method [21]. Then, the model was applied to a mining industry company using the Fuzzy AHP method instead of the AHP to take into account the uncertainty and vagueness of the judgments given by experts when establishing the comparison matrices, then the FCEM method to calculate the maturity level [22].

In this work, the measurement methodologies proposed consist in combining the Fuzzy ANP method with the FCEM method. The FANP is used instead of the FAHP to consider the interdependence between the five factors of the HOFMM which impacts the weightings of the elements.

4.1 Fuzzy ANP

The purpose of combining fuzzy logic and ANP method is overcome with the inaccuracy and ambiguity of the decisions taken by experts when judging the importance of elements.

The FANP is used to calculate the weightings of factors and sub-factors.

By following the steps below, weights of factors and sub-factors are calculated using the FANP method that utilizes the triangular fuzzy numbers (TFNs). [23, 25, 26, 27].

Step 1: Identify the elements of the model (Goal, factors and sub-factors). Then, structure hierarchically the ANP model based on the elements identified.

Step 2: Utilize the Fuzzy Triangular scale suggested by Kahraman et al. [28], given in Table 7 and Figure 5, to compute the factors and sub-factors local

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weights by undertaking the element's pairwise comparisons. It is assumed in this step that there is no dependence between factors.

Step 3: First, use the same scale (Table 7) to determine the dependence matrix from the relative weights (RW) obtained with the inner dependence matrices that consider the effect of each factor on the others.

Finally, calculate the interdependent weights (IW) by multiplying the local weights of factors (Obtained in step 2) with the dependence matrix.

Table 7: Linguistic scale for relative importance

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

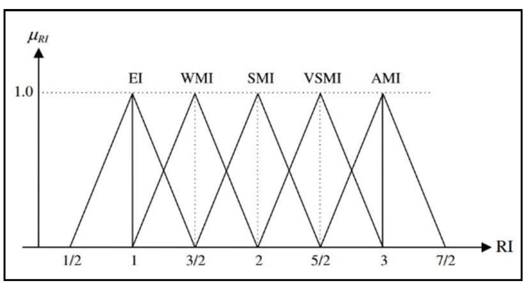

Figure 5: Linguistic scale for relative importance

To calculate the weights of the factors and sub-factors from the comparison matrices in the steps above (2 and 3), the Chang's Fuzzy AHP method is used as it is easy and simple to apply.

The steps of the extent analysis approach proposed by Chang are defined below:

X = $\{x_1, x_2, \ldots, x_n\}$ is defined as an object set and U = $\{u_1, u_2, \ldots, u_m\}$ is a goal set.

For each x_i (object), an analysis is performed for each possible goal g_i. Thus for each x_i, m extent analysis are obtained:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m \quad i=1, 2, \ldots, n. \qquad (1)$$

Where all $M_{g_i}^j$ (j=1, 2, …, *m*) are TFNs. A TFN is denoted (*l,m,u*).

1) Compute the fuzzy synthetic value *Si* for the *i*-th object (x_i) as follows:

$$S_i = \sum_{j=1}^{n} M_{g_i}^j \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \qquad (2)$$

Where;

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \qquad (3)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{j=1}^{n} m_i, \sum_{i=1}^{n} u_i\right) \quad (4)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{j=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right] \quad (5)$$

2) Calculate the normalized weight vector defined by;

For *k,i* =1, …, *n, k≠i*

$$W = \left(\min V(S_1 \geq S_k), \ldots, \min V(S_i \geq S_k), \ldots, \min V(S_n \geq S_k)\right)^T \quad (6)$$

The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1) = sup\left[\min\left(\mu_{S_1}(x), \mu_{S_2}(y)\right)\right] =$$

$$\text{hgt}(M_2 \cap M_1) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \qquad (7)$$

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i can be expressed by:

$$V(M \geq M_1, M_2, \ldots, M_k) = V[(M \geq M_1), \ldots, (M \geq M_k)] = \min V(M \geq M_i), i=1, \ldots, k. \qquad (8)$$

4.2 Fuzzy Comprehensive Evaluation Method

The FCEM is a mathematical tool that helps deciders to make a decision in a complex and fuzzy environment or system by using fuzzy sets and theories instead of classical logic [21, 22]. In this work, it is used to determine the maturity level of each element of the model as well as the overall maturity level, as follows:

Assume that *U*=$\{U_1, U_2, \ldots, U_p\}$ is defined as an evaluation set.

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Step 1: From the evaluations given by the decision makers, the fuzzy relationship matrix R_i is established.

$$R_i = \begin{pmatrix} R_{i1} \\ \vdots \\ R_{ij} \\ \vdots \\ R_{im} \end{pmatrix} = \begin{bmatrix} r_{i11} & \cdots & r_{i1p} \\ \vdots & r_{ijk} & \vdots \\ r_{im1} & \cdots & r_{imp} \end{bmatrix} \quad (9)$$

R_{ij} is a fuzzy relationship from sub-factors to U.
Where: *i*=1, …, *n* is the number of factors to be assessed.
j=1, …, *m* is the second index of *I* and *m* is the number of sub-factors.
k=1, …, *p, k* is the assessment level and p is the number of assessment levels

$r_{ijk} = l_{ijk} / \beta$ (10)

$\beta = \sum_{k=1}^{k=p} l_{ijk}$ is defined as the total number of experts.

Step 2: Compute the matrix R named the first-class index membership matrix.

$$R = W_i \circ R_i = \begin{bmatrix} r_{11} & \cdots & r_{1p} \\ \vdots & r_{ik} & \vdots \\ r_{n1} & \cdots & r_{np} \end{bmatrix} \quad (11)$$

$W_i = (W_1 \ \cdots \ W_i \ \cdots \ W_m)$ is the weight vector of sub-factors.

Step 3: Finally, get the maturity vector M:

$$M = W\,R = (r_1 \ \cdots \ r_p) \quad (12)$$

$W = (W_1 \ \cdots \ W_i \ \cdots \ W_n)$ is the weight vector of factors.

The maximum membership degree law is utilized in determining the maturity level of factors using the results obtained in step 2, then the overall maturity level from the maturity vector M.

5. CASE STUDY

In order to define the current HOF maturity within a Moroccan factory of a multinational auto-parts manufacturing and determine the objectives to be reached to enhance the maturity level, the HOFMM is implemented using the combination of the two methods presented in this paper. To carry out the study properly and to have results close to reality, a group of decision makers (Manager, supervisor and operator) is selected from each department of the plant (Production, Quality, Maintenance, Engineering, Logistics, IT, HR) to form a group of experts of 21 persons.

5.1 Results

Figure 6 gives an overview of the ANP hierarchical model structed on the basis of the HOFMM elements suggested above.

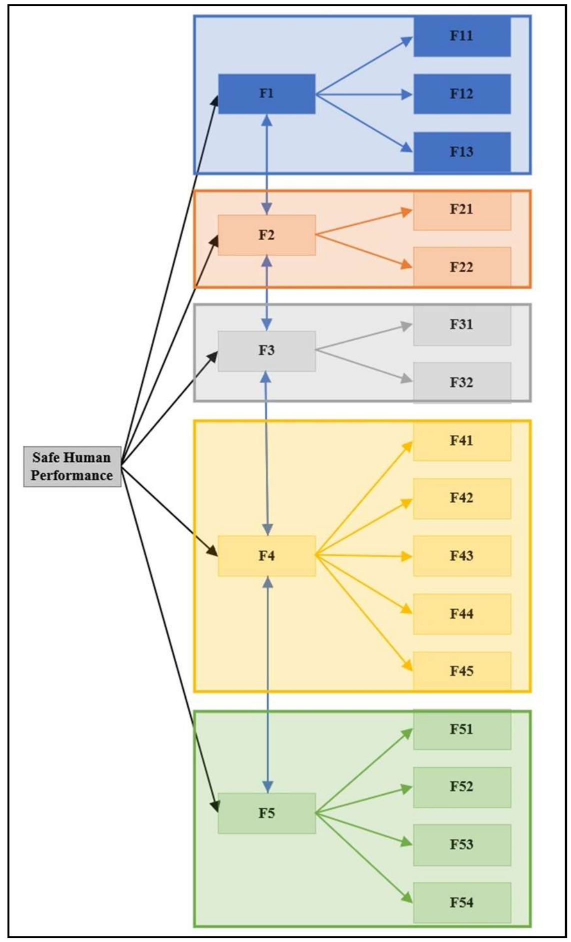

Figure 6: ANP hierarchical model of the HOFMM

The experts group established the pairwise comparison matrices below according to the fuzzy linguistic scale presented in Table 7. Then, the Chang's method is used to calculate the local weights (LW) of the HOFMM elements.

From Table 8, the local weights of factors are calculated as follow:

1) S_{F1}= (0.18, 0.28, 0.41) ; S_{F2}= (0.09, 0.13, 0.24) ; S_{F3}= (0.13, 0.19, 0.28) ; S_{F4}= (0.12, 0.18, 0.27) ; S_{F5}= (0.13, 0.22, 0.34).

2) V ($S_{F1} \geq S_{F2}$) = 1; V ($S_{F1} \geq S_{F3}$) = 1; V ($S_{F1} \geq S_{F4}$) = 1; V ($S_{F1} \geq S_{F5}$) = 1.

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$V(S_{F2} \geq S_{F1}) = 0.32$; $V(S_{F2} \geq S_{F3}) = 0.67$;
$V(S_{F2} \geq S_{F4}) = 0.75$; $V(S_{F2} \geq S_{F5}) = 0.56$.

$V(S_{F3} \geq S_{F1}) = 0.55$; $V(S_{F3} \geq S_{F2}) = 1$;
$V(S_{F3} \geq S_{F4}) = 1$; $V(S_{F3} \geq S_{F5}) = 1$.

$V(S_{F4} \geq S_{F1}) = 0.50$; $V(S_{F4} \geq S_{F2}) = 1$;
$V(S_{F4} \geq S_{F3}) = 0.92$; $V(S_{F4} \geq S_{F5}) = 0.77$.

$V(S_{F5} \geq S_{F1}) = 0.75$; $V(S_{F5} \geq S_{F2}) = 1$;
$V(S_{F5} \geq S_{F3}) = 1$; $V(S_{F5} \geq S_{F4}) = 1$.

$V(S_{F1} \geq S_{F2}, S_{F3}, S_{F4}, S_{F5}) = 1$;
$V(S_{F2} \geq S_{F1}, S_{F3}, S_{F4}, S_{F5}) = 0.32$;
$V(S_{F3} \geq S_{F1}, S_{F2}, S_{F4}, S_{F5}) = 0.55$;
$V(S_{F4} \geq S_{F1}, S_{F2}, S_{F3}, S_{F5}) = 0.50$;
$V(S_{F5} \geq S_{F1}, S_{F2}, S_{F3}, S_{F4}) = 0.75$.

Then, the weight vector of factors is obtained:

$$W = (1, 0.32, 0.55, 0.50, 0.75)^T = (0.32, 0.10, 0.18, 0.16, 0.24).$$

Using the same scale, the experts performed the inner dependence matrices shown in Tables 14,15,16,17,18 to calculate the relative weights (RW).

The relative weights are used to form the dependence matrix that we multiply by the local weights of factors to obtain the interdependent weights.

$$\begin{pmatrix} 1 & 0.09 & 0.07 & 0.16 & 0.35 \\ 0.13 & 1 & 0.22 & 0.29 & 0.07 \\ 0.31 & 0.38 & 1 & 033 & 0.20 \\ 0.23 & 0.34 & 0.33 & 1 & 0.38 \\ 0.33 & 0.19 & 0.38 & 0.22 & 1 \end{pmatrix} \times \begin{pmatrix} 0.32 \\ 0.10 \\ 0.18 \\ 0.16 \\ 0.24 \end{pmatrix}$$

$$= \begin{pmatrix} 0.45 & 0.24 & 0.42 & 0.42 & 0.47 \end{pmatrix}$$

The normalization of the obtained vector gives the values of interdependent weights (IW) as follows:

$$W = \begin{pmatrix} 0.23 & 0.12 & 0.21 & 0.21 & 0.24 \end{pmatrix}$$

The group of experts assesses the maturity of each sub-factor using the key questions presented above (Tables 2,3,4,5,6) to obtain the first class-index membership matrix presented in Table 19. Then, the local weights of sub-factors are utilized to compute the second class-index membership matrix shown in Table 20.

Finally, we get the overall maturity vector by multiplying the first-class matrix with the interdependent weights:

$$HOMM = (0.05, 0.16, 0.30, 0.33, 0.16)$$

5.2 Discussion

According to the overall maturity vector obtained and the law of maximum membership degree, the maturity level of the auto-parts manufacturing factory is "Managed". Which means that there is a strong consideration of human and organizational factors in the company's policy and there are also planned and implemented procedures in this sense.

Figure 7 gives an overview of the maturity level of each factor using the same law and the second class-index membership matrix (Table 20). The first factor "Design" is at level 5 "Continually improving", factors "Staffing and Culture" are at level 4 "Managed", but both "Training and Conditions" are at level 3 "Planned".

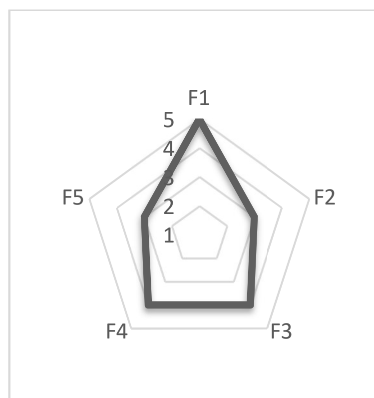

Figure 7: Maturity levels of factors

From the maturity vector, we can see that the plant is at the "Managed" level but close to "Planned", so it has just made the transition between the two levels, which requires improvements to get closer to the fifth level and then reach it.

First, improvements should target the factor "Conditions" since it has the highest weighting which means that it has a significant impact on human performance, then enhance the factor "Training" as both are still at level 3.

From the first class-index matrix (Table 19), the sub-factors to be improved related to the two factors "Training and Conditions" are identified by choosing those with the lowest ratings.

Based on the expert's assessments, it is recommended to focus on effective training programs to identify training needs and their impact on employees using the ADDIE model shown in Figure 8. [29]

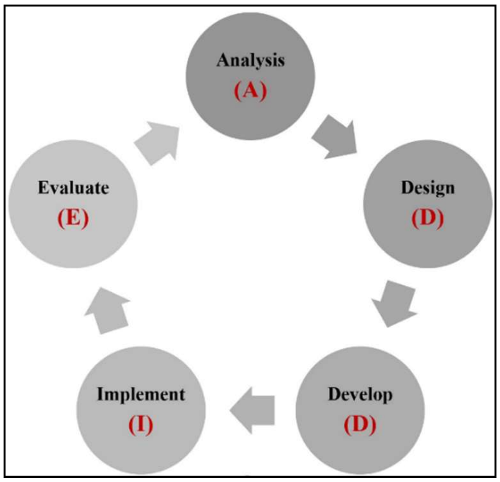

Figure 8: ADDIE model

To enhance the current situation of the "Conditions" factor, it is necessary to put in place new procedures related to the sub-factors “Morale & Motivation, Stress and Workload”. To that end, it is suggested to use the PDCA method (Figure 9) which is a continuous improvement process and managing change [30].

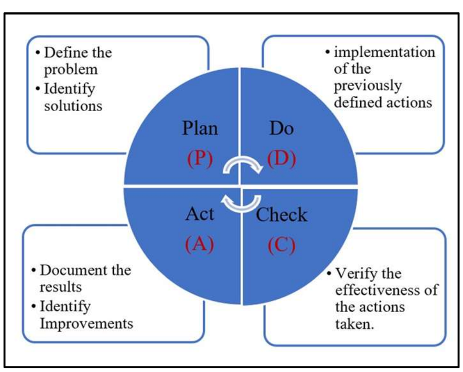

Figure 9: PDCA cycle

6. CONCLUSION

Taking human and organizational factors into account in all the processes of the company ensures safe and favorable working conditions, which positively impacts human performance at work. But many companies who wish to do so find it difficult to choose the most suitable method to integrate them.

The approach suggested by the researchers is to first assess the company's level of maturity and then identify weak areas that require changes or improvements using a maturity model and a measurement method, which differs from one model to another.

This paper presents a HOFMM implemented in an auto-parts manufacturing factory, using the Fuzzy ANP and the FCEM seen that the measurement step can be considered as a multi-criteria decision-making problem. The model defines a set of factors and sub-factors related to HOF, as well as key questions that facilitate the assessment done by experts.

The objective of the study is not only to determine the overall level of maturity, but also the level of the factors through the evaluation of sub-factors carried out by the selected experts, which allows to define the elements to be enhanced. Efficient improvement methods are proposed to support the company in the process of improving low-maturity factors, such as the PDCA method and the ADDIE model.

The HOFMM will be reused in the same factory to check whether the company has achieved the objectives defined after the study carried out, using the proposed improvement methods.

Table 8: LW of factors

GOAL	F1	F2	F3	F4	F5	LW
F1	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)	(1,3/2,2)	(1,1,1)	0.32
F2	(2/5,1/2,2/3)	(1,1,1)	(2/5,1/2,2/3)	(1/2,2/3,1)	(2/3,1,2)	0.10
F3	(2/5,1/2,2/3)	(3/2,2,5/2)	(1,1,1)	(1,1,1)	(1/2,2/3,1)	0.18
F4	(1/2,2/3,1)	(1,3/2,2)	(1,1,1)	(1,1,1)	(1/2,2/3,1)	0.16
F5	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	0.24

Table 9: LW of F1 sub-factors

F1	F11	F12	F13	LW
F11	(1,1,1)	(1,3/2,2)	(1,3/2,2)	0.45
F12	(1/2,2/3,1)	(1,1,1)	(3/2,2,5/2)	0.41
F13	(1/2,2/3,1)	(2/5,1/2,2/3)	(1,1,1)	0.15

Table 10: LW of F2 sub-factors

F2	F21	F22	LW
F21	(1,1,1)	(1,3/2,2)	0.68
F22	(1/2,2/3,1)	(1,1,1)	0.32

Table 11: LW of F3 sub-factors

F3	F31	F32	LW
F31	(1,1,1)	(1,3/2,2)	0.68
F32	(1/2,2/3,1)	(1,1,1)	0.32

Table 12: LW of F4 sub-factors

F4	F41	F42	F43	F44	F45	LW
F41	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1,3/2,2)	(1,3/2,2)	0.26
F42	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1,3/2,2)	0.23
F43	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	0.18
F44	(1/2,2/3,1)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)	0.17
F45	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)	0.15

Table 13: LW of F5 sub-factors

F5	F51	F52	F53	F54	LW
F51	(1,1,1)	(2/3,1,2)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	0.15
F52	(1/2,1,3/2)	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	0.17
F53	(3/2,2,5/2)	(1,3/2,2)	(1,1,1)	(1,3/2,2)	0.36
F54	(3/2,2,5/2)	(1,3/2,2)	(1/2,2/3,1)	(1,1,1)	0.31

Table 14: Inner dependence matrix of F1

F1	F2	F3	F4	F5	RW
F2	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(2/5,1/2,2/3)	0.13
F3	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(2/3,1,2)	0.31
F4	(1,3/2,2)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	0.23
F5	(3/2,2,5/2)	(1/2,1,3/2)	(1,3/2,2)	(1,1,1)	0.33

Table 15: Inner dependence matrix of F2

F2	F1	F3	F4	F5	RW
F1	(1,1,1)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1/2,2/3,1)	0.09
F3	(1,3/2,2)	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	0.38
F4	(3/2,2,5/2)	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	0.34
F5	(1,3/2,2)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1,1,1)	0.19

Table16: Inner dependence matrix of F3

F3	F1	F2	F4	F5	RW
F1	(1,1,1)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1/2,2/3,1)	0.07
F2	(1,3/2,2)	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	0.22
F4	(3/2,2,5/2)	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)	0.33
F5	(1,3/2,2)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1,1,1)	0.38

Table 17: Inner dependence matrix of F4

F4	F1	F2	F3	F5	RW
F1	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	0.16
F2	(1,3/2,2)	(1,1,1)	(1,1,1)	(1/2,1,3/2)	0.29
F3	(1,3/2,2)	(1,1,1)	(1,1,1)	(1,3/2,2)	0.33
F5	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)	(1,1,1)	0.22

Table18: Inner dependence matrix of F5

F5	F1	F2	F3	F4	RW
F1	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	(2/3,1,2)	0.35
F2	(2/5,1/2,2/3)	(1,1,1)	(1/2,2/3,1)	(2/5,1/2,2/3)	0.07
F3	(1/2,2/3,1)	(1,3/2,2)	(1,1,1)	(2/5,1/2,2/3)	0.20
F4	(1/2,1,3/2)	(3/2,2,5/2)	(3/2,2,5/2)	(1,1,1)	0.38

Table 19: First-class index membership matrix

Sub-Factors	LW	Assessment Levels				
		Basic	Transitional	Planned	Managed	Continually improving
F11	0.45	0.00	0.00	0.00	0.29	0.71
F12	0.40	0.00	0.00	0.10	0.48	0.43
F13	0.15	0.00	0.10	0.48	0.43	0.00
F21	0.68	0.00	0.33	0.52	0.14	0.00
F22	0.32	0.24	0.33	0.38	0.05	0.00
F31	0.68	0.00	0.00	0.24	0.57	0.19
F32	0.32	0.14	0.62	0.19	0.05	0.00
F41	0.26	0.00	0.00	0.43	0.48	0.10
F42	0.23	0.00	0.00	0.38	0.52	0.10
F43	0.19	0.00	0.00	0.43	0.57	0.00
F44	0.17	0.00	0.00	0.24	0.71	0.05
F45	0.15	0.33	0.38	0.29	0.00	0.00
F51	0.15	0.43	0.52	0.05	0.00	0.00
F52	0.17	0.24	0.67	0.10	0.00	0.00
F53	0.36	0.00	0.24	0.76	0.00	0.00
F54	0.32	0.00	0.00	0.33	0.52	0.14

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Table 20: Second-class index membership matrix

Factors	IW	Assessment Levels				
		Basic	Transitional	Planned	Managed	Continually improving
F1	0.22	0.00	0.01	0.11	0.39	0.49
F2	0.12	0.07	0.33	0.47	0.13	0.00
F3	0.21	0.05	0.20	0.22	0.40	0.13
F4	0.21	0.04	0.06	0.37	0.47	0.06
F5	0.24	0.11	0.28	0.40	0.17	0.04

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