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A Fuzzy Comprehensive Evaluation Model for Ergonomics in an Industrial Zone

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***Abstract*:** *In this paper we will evaluate the level of ergonomics in an existing industrial zone. This evaluation will enable the community to ensure that the industrial zone meets the expectations of the companies and the involved actors, to identify improvements track and to initiate actions. The aim of this approach is to improve the quality of the area, to give it the maximum chance of perpetuating direct and indirect jobs, to maintain the fiscal resources and to preserve environmental resources (water, energy, landscape, air, etc.).To meet this evaluation objective, we proposed a model based on the combination of the AHP method and the fuzzy comprehensive technical evaluation. Considering the fuzzy characteristics of factors influencing the level of ergonomics in an industrial zone, a two-level evaluation index system was established. The degree of adherence of factors is determined by the knowledge and experience of the experts. The weight of each factor is determined by the AHP method and a final judgment matrix is determined by the end. This method made the ergonomic evaluation turn from the qualitative to the quantitative.*

Keywords: *fuzzy set, Analytic Hierarchy Process, industrial zone, ergonomics evaluation.*

1. Introduction

In most cases, the industrial zone is a space setting up by local authorities in order to be marketed to companies for the purpose of carrying out their economic activities. There are approximately 80 industrial parks in Morocco for a cumulative area of 4600 hectares [1]. They comprise 25% of jobs and one third of firms. The purpose of these sites is to strengthen and structure the local economic fabric through an adapted land and property supply. If the initial vocation of the first "Industrial Zones" was to leave the factories away from the population, by regrouping the polluting activities outside the city, today we try to make these spaces more human.

Therefore, to ensure the quality of a zone of activity over the long term, it will be wise to implement an ergonomic evaluation of the area of activity to monitor its evolution over time. This assessment will help to understand the strengths and weaknesses of the area and to consider, in the short, medium or long term, the measures to be implemented to correct deficiencies or failures. In the light of this observation, the idea of evaluating ergonomics in an industrial zone is hardly mentioned in the literature, but it is part of the ''urban ergonomics'' concept, of which several research studies have been carried out. The transfer of the ergonomics of a city or of an urban space in general to the ergonomics of an industrial zone, although still little rose in the literature, seems fruitful. As early as the 1970s, the psychologist J.C Sperandio (1976) [2,3] studied the extent to which ergonomics could be applied to the built environment, which is understood to include housing and working buildings on the one hand, and by neighbourhoods and towns (or villages), including roads, up to the planning of the territory, on the other hand. Few studies on the evaluation of urban ergonomics in the literature has been performed, the study of Afacan and Erburg (2009) [4] highlights the evaluation heuristics as a way which can feed the current practice of buildings design to meet the requirements of universal and ergonomic design. It applies in a shopping mall an iterative series of evaluation to seven universal principles of design which are defines as a set of heuristics, aiming to accomplish a gainful evaluation process. There is also a study implanted in Japan focuses on the analysis and the solutions for collisions at uncontrolled intersections in communities, in very accidental situations where aggressive countermeasures were not taken, focusing on human factors [5].

In order to evaluate ergonomics in an industrial park we propose the Analytical Hierarchy Process (AHP) combined with the fuzzy comprehensive evaluation method. The fuzzy comprehensive evaluation method [6] is a powerful tool that may be used to make a decisions when multiple and conflicting criteria are present. It also allows managers to structure the complex problems they face by making judgments based on their experience and available information.

The paper is focus on developing the fuzzy comprehensive evaluation model; calculating weights of factors and sub-factors with the AHP method; calculating the final judgment matrix with the fuzzy model and analysing the evaluation results by the end.

2. 2. Fuzzy Comprehensive Evaluation Model

2.1. A factor set

In the practical case, we need to evaluate something based on multiple factors instead of a single factor: this is called a multi-criteria approach... Here, evaluation means determining merits (good) and bad things according to the given conditions. Therefore, a comprehensive evaluation is a method used to solve problems that include many evaluation factors. The evaluation factor procedure start with the determination of the factor set. A set of factors is composed of factors that influence the evaluation of an object. It is defined as:

$$U= \{u_1, u_2\ldots u_m\} \tag{1}$$

With u_i (i=1,2,…,m) being ith factor of the first class, u_i is determined by nth factor of the second class as $ui = (u_{i1},u_{i2},\ldots,u_{ik})$, k the number of sub-factors for each factor.

2.2. Defining the assessment set

A The assessment set presents the results of fuzzy evaluation, it is expressed as $V= \{v_1, v_2\ldots v_n\}$, where n is the number of levels. Therefore, we propose a qualitative partition of five levels:

$$V= \{\text{Good, less good, general, poor, bad}\} \tag{2}$$

Fuzzy relationship matrix is determined by experts' knowledge and experience. The graded marks are then balanced and integrated. Finally, we calculated hierarchically every membership degree of the factor set for every element of the assessment set.

2.3. Determining the set of factor's weight

The weight coefficient matrix of each class is defined as:

$$A= (a_1, a_2\ldots a_m) \qquad \text{where} \qquad \sum_{i=1}^{m} ai = 1 \tag{3}$$

2.4. Determining the fuzzy judgment matrix

The judgment matrix result of m evaluation factors and n level is:

$$R = \begin{pmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{pmatrix} \tag{4}$$

Where $0 \leqslant rij \leqslant 1$, i= 1,2⋯ ,m , j=1,2⋯,n. rij is the fuzzy evaluation result of the ith factor by the jth level.

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2.5. Fuzzy comprehensive evaluating set

Using the fuzzy hierarchy comprehensive evaluation calculation model B = A • R. The fuzzy comprehensive evaluation vector set is:

$$B = A \bullet R = (a_1, a_2 \dots a_m) \bullet \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{pmatrix} \quad (5)$$

.

Where bi (i=1, 2… n) is the fuzzy comprehensive evaluation vector.

In this equation, m is the number of evaluation factors, n is the number of levels. The use of a multi-level fuzzy comprehensive assessment method means that the fuzzy global evaluation should be carried out from the lowest class to the top class until the final result is obtained [7].The result of the evaluation depends on the maximum value of B:

$$b_k = \max_{1 \le i \le n} \{b_i\} \quad (6)$$

2.6. Analytic Hierarchy Process AHP to determine factor weights

The AHP method consists in representing a decision problem by a hierarchical structure that reflect the interactions between the various elements of the problem, then making paired comparisons of the elements of the hierarchy, and finally determining the priorities of the actions:

Step 1: Divide the problem into a hierarchy of interconnected elements. The top of the hierarchy is the 'objective', and in the lower levels, the elements contributing to this objective. The last level is that of actions [6, 8].

Step 2: Perform pair-wise comparisons of elements of each hierarchical level with an element of the higher hierarchy level. This step helps to construct matrices of comparisons. The values of these matrices are obtained by transforming the judgments into numerical values according to the Saaty scale [9]:

TABLE I: Binary Comparison scale of Saaty

1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very to extremely strongly preferred
9	Extremely preferred

Step 3: Determine the relative importance of the elements by calculating the eigenvectors corresponding to the maximum eigenvalues of the matrices of comparisons.

Step 4: Check the judgments consistency. First, we calculate the consistency index CI.

$$CI = (\lambda_{max} - n)/ (n-1) \quad (7)$$

Where λmax is the maximum eigenvalue corresponding to the matrix of the pairwise comparisons and n is the number of elements compared.

Second, the coherence ratio (CR) is calculated by:

$$CR = CI / RI \quad (8)$$

Where RI is the average consistency index obtained by generating judgment matrices of the same size randomly. The table of Random Index is shown below [9]:

TABLE II: Table of Random Index

n	1	2	3	4	5	6	7	8	9
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45

A CR value less than 10% is generally acceptable; otherwise pairwise comparisons need to be revised to reduce inconsistencies.

Step 5: Determination of the relative performance of each action and selecting the best design alternative.

3. Case of Study

In this study, four main criteria of evaluation of ergonomics in an industrial zone were confirmed on the basis of the frequency of their occurrence in the various sources: management and economical use of resources C1, local development and attractiveness C2, quality living and urban comfort C3, and the environmental quality C4. These four main criteria are drawn from different approaches and references:

•The MEFISTO reference system (Charlot-Valdieu and Outrequin, 2009) for sustainable development, which is a tool for assessing quality in an urban space… [10]

•ISO 37120:2014: As part of a new series of International Standards being developed for an integrated approach to sustainable development and resilience, the indicators and associated test methods in this International Standard have been developed in order to help cities measure performance management of city services and quality of life over time [11].

•ISO 14031: describes environmental performance evaluation as a regularly recurring process as well as placing general requirements for indicators. It also lists detailed examples for each evaluation area [12]. The mainly influencing factors for the ergonomics in an industrial zone are illustrated in table 3:

TABLE III: The Hierarchy Factor Structure of Ergonomics in an Industrial Zon

	1st class factors	2nd class factors (sub-factors)
Ergonomics of an industrial zone C	Management and economical use of ressources C_1	Economy C_{11}
		Maintenance C_{12}
		Management C_{13}
	Local development and attractiveness C_2	Services offer C_{21}
		Safety and security C_{22}
		Leisure and entertainment C_{23}
		Mobility C_{24}
		Attractiveness C_{25}
	Quality liviing and urban comfort C_3	Accessibility C_{31}
		Architecture C_{32}
		Visuel quality C_{33}
	Environmental quality C_4	Noise, water, air C_{41}
		Climate confort C_{42}
		Sanitation C_{43}

Utilizing the AHP method, the pairwise comparison matrix, weight vector, the maximum eigenvalue λmax and the consistency ratio CR for ergonomics in an industrial zone factors are obtained in table 4.

TABLE IV: Relative Weights Influencing Ergonomics in an Industrial Zone

Sub-factors influencing ergonomics in the industrial zone C	C_1	C_2	C_3	C_4	weight vector	λ_{MAX}	CR
C_1	1	1/4	3	1/5	0,118		
C_2	4	1	6	2	0,479	4,216	0,08<0,1
C_3	1/3	1/6	1	1/4	0,064		
C_4	5	1/2	4	1	0,339		

Thus, the set of factor's weight influencing ergonomics in the industrial zone can be regarded as:

$$A = \begin{pmatrix} 0{,}118 & 0{,}479 & 0{,}064 & 0{,}339 \end{pmatrix}$$

Similarly, the factor weight set influencing the management and economical use of resources, the local development and attractiveness, the quality living and urban comfort and the environmental quality can be regarded as:

$$A_1 = \begin{pmatrix} 0{,}082 & 0{,}682 & 0{,}236 \end{pmatrix} \qquad A_3 = \begin{pmatrix} 0{,}727 & 0{,}091 & 0{,}182 \end{pmatrix}$$

$$A_2 = \begin{pmatrix} 0{,}394 & 0{,}353 & 0{,}048 & 0{,}137 & 0{,}068 \end{pmatrix} \qquad A_4 = \begin{pmatrix} 0{,}238 & 0{,}136 & 0{,}625 \end{pmatrix}$$

After having determined the factors influencing ergonomics in the industrial zone are evaluated according to the five levels already defined in the assessment set: V= {Good, less good, general, poor, bad}. Based on the evaluation of experts, the result of judgment matrix is established as:

TABLE V: The Judgment Matrix of the Evaluated System

1st class factors C_i	2nd class factor C_{ij}	Levels good	Less good	general	poor	bad
	C_{11}	0	0,6	0,2	0,2	0
C_1	C_{12}	0	0,5	0,2	0,3	0
	C_{13}	0	0	0	0,5	0,5
	C_{21}	0	0	0,3333	0,6666	0
	C_{22}	0	0	1	0	0
C_2	C_{23}	0	0	0	0,5	0,5
	C_{24}	0,66666	0,3333	0	0	0
	C_{25}	0,2	0,2	0,6	0	0
	C_{31}	0	0	1	0	0
C_3	C_{32}	0	0	0,5	0,5	0
	C_{33}	0	0	0,2	0,3	0,5
	C_{41}	0	0	0	0	1
C_4	C_{42}	0	0	0	1	0
	C_{43}	0,4	0,4	0,2	0	0

Therefore, the respective evaluation matrices R_1, R_2, R_3 and R_4 are:

$$R_1 = \begin{pmatrix} 0 & 0{,}6 & 0{,}2 & 0{,}2 & 0 \\ 0 & 0{,}5 & 0{,}2 & 0{,}3 & 0 \\ 0 & 0 & 0 & 0{,}5 & 0{,}5 \end{pmatrix} \qquad R_2 = \begin{pmatrix} 0 & 0 & 0{,}333 & 0{,}666 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0{,}5 & 0{,}5 \\ 0{,}666 & 0{,}333 & 0 & 0 & 0 \\ 0{,}2 & 0{,}2 & 0{,}6 & 0 & 0 \end{pmatrix}$$

$$R_3=\begin{pmatrix}0 & 0 & 1 & 0 & 0\\ 0 & 0 & 0,5 & 0,5 & 0\\ 0 & 0 & 0,2 & 0,3 & 0,5\end{pmatrix} \qquad R_4=\begin{pmatrix}0 & 0 & 0 & 0 & 1\\ 0 & 0 & 0 & 1 & 0\\ 0,4 & 0,4 & 0,2 & 0 & 0\end{pmatrix}$$

The first order fuzzy comprehensive evaluation is expressed as:

$B_1= A_1 \text{ o } R_1 = (0 \quad 0,390 \quad 0,152 \quad 0,339 \quad 0,118)$

$B_2 = A_2 \text{ o } R_2 = (0,104 \quad 0,059 \quad 0,525 \quad 0,286 \quad 0,024)$

$B_3 = A_3 \text{ o } R_3 = (0 \quad 0 \quad 0,808 \quad 0,100 \quad 0,091)$

$B_4 = A_4 \text{ o } R_4 = (0,250 \quad 0,250 \quad 0,125 \quad 0,136 \quad 0,238)$

The second order fuzzy comprehensive evaluation matrix is:

$$B= A \text{ o } R = A \text{ o } \begin{pmatrix}A_1 \text{ o } R_1\\ A_2 \text{ o } R_2\\ A_3 \text{ o } R_3\\ A_4 \text{ o } R_4\end{pmatrix}$$

$$B=\begin{pmatrix}0,118\\ 0,479\\ 0,064\\ 0,339\end{pmatrix} \text{ o } \begin{pmatrix}0 & 0,390 & 0,152 & 0,339 & 0,118\\ 0,104 & 0,059 & 0,525 & 0,286 & 0,024\\ 0 & 0 & 0,808 & 0,100 & 0,091\\ 0,250 & 0,250 & 0,125 & 0,136 & 0,238\end{pmatrix}$$

The final result is:

$B = (0,134 \quad 0,159 \quad 0,363 \quad 0,229 \quad 0,111)$

According to the biggest membership of the fuzzy comprehensive evaluation set, the level of ergonomics in an industrial zone is ‘’general’’.

4. Analysis of Evaluation Result

According to the fuzzy comprehensive evaluation result, the level of ergonomics in the industrial park is "general". It illustrates that the industrial park ergonomic conditions meet the basic necessary for urban sustainable development, but there is a large space to improve the life quality of employees and attract more companies to come and settle there.

According to the set of factor’s weight A, the biggest influencing factor is local development and attractiveness (C2). So it is preferable to:

-Ensure the safety of displacements such as, for example, the existence of pedestrian-vehicle interfaces, and surveillance systems.

-Focus on the efficient of mobility: parking space offer and reception spaces offer for poisonous flows in the vicinity of the stations...

-Guarantee a functional attractiveness: develop the offers of services (restaurant, pharmacy, nursery ...), availability of ICT for users.

5. Conclusion

In this research, we proposed the fuzzy comprehension evaluation method to evaluate the level of ergonomics in an industrial zone. The use of this technique is very innovative and operational. We calculated the factor weights of each hierarchy using AHP and we verified the rationality of the weights using the judgment matrix to ascertain whether their consistency is satisfactory or not. Among the main advantages of this technique is that the factors influencing ergonomics in an industrial zone can be represented directly by different layers and subsequently can guarantee the objectivity and effectiveness of the overall assessment.

The results and analyses proposed by this research are intended to guide local actors, and in particular elected officials, in the implementation of their projects to create or reclassify industrial spaces of activity on their territory, in an ergonomic frame. Of course, the perfection of this method must be compared with other methods such as the DEA, the raw set, and the entropy theory that have been useful in another field. It will be studied in future research for further progress.

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