APPLICATION OF AHP TO PROGRAMMING FOR TREATMENT OF THE HARM CAUSED BY DUST AND TOXICANTS IN TIANJIN

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ABSTRACT

In this paper we have determined the degrees of harm caused by dust and toxicants by application of AHP, which provides the data necessary for harm treatment programming in Tianjin.

1. Introduction

Dust and toxicants do a lot of harm to the health and even lives of workers who work in a polluted environment. To protect the workers by treating the harm step by step according to the plan is a major policy decision of Tianjin municipality.

The aim of our harm treatment programming is how to obtain the best effect of the treatment at the limited expenses. We interpret the treatment effect as annihilating the harm, and the best treatment effect, the maximum amount of annihilated harm. Therefore, it is necessary to describe quantitatively the harm caused by dust and toxicants, which we refer to as the "degree of harm". According to related experts, the degree of harm depends on the following five factors:

- The supernormal multiple (i.e.

  $$\frac{\text{The maximum value under supervision}}{\text{The standard value under supervision}} - 1);$$

- The number of victims;
- The number of the sick;
- The ratio of the number of people under supervision to the total number of victims;
- The number of the dead.

Therefore, it becomes the key problem in harm treatment programming to determine scientifically the weights of these five factors individually and thereby to find the degree of harm as a measurement scale of all sorts of harm. We have got satisfactory results in applying AHP to determination of degrees of harm caused by dust and toxicants.

In this paper, we shall first develop the mathematical model for harm treatment programming, and then describe how to use AHP to find the degrees of harm.

2. Mathematical Model for Harm Treatment Programming

The treatment that meets our state standard means that the amount of dust and toxicants contained in a working environment is not gone beyond the standard. For instance, the lead smoke shouldn't exceed the standard value 0.03 mg/m^3.
The mathematical model for harm treatment programming is as follows:

$$\text{Max } z = \sum_{j=1}^{n} \sum_{i \in s_j} c_{ij} x_{ij} \quad (1)$$

$$\text{s.t.} \quad \sum_{j=1}^{n} \sum_{i \in s_j} k_{ij} x_{ij} \leqslant k \quad (2)$$

$$\sum_{j} x_{ij} \geqslant 1 \quad (i \in s) \quad (3)$$

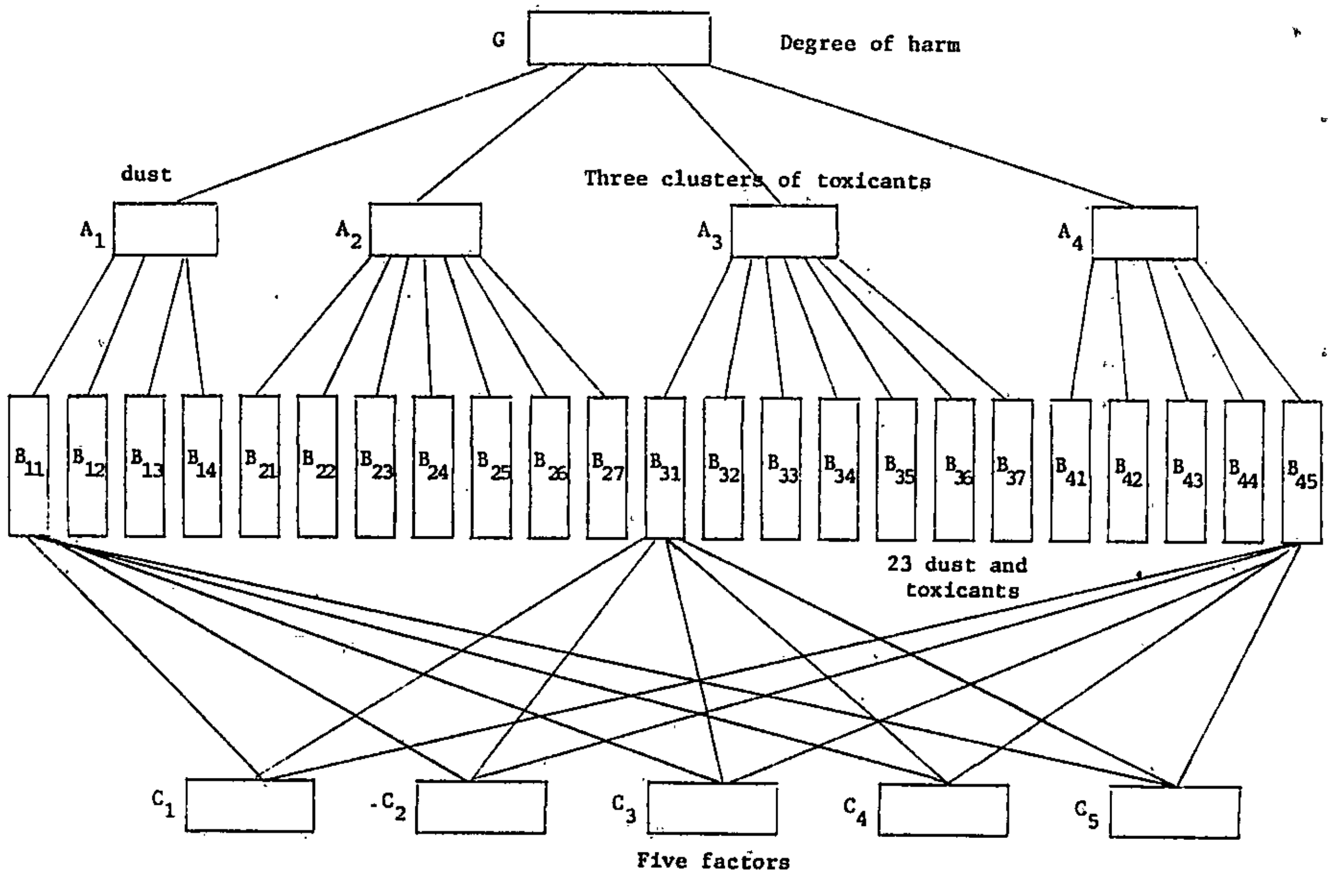
$$x_{ij} = 0 \text{ or } 1 \quad (4)$$

where z, represents the total amount of harm caused by dust and toxicants;
n, the number of factories which need to clear their working environments of harmful substances;
j, the ordinal number of factories which need to treat their working environments;
i, the ordinal number of dust or toxicants;
s_j, the set of dust and toxicants in factory No.j;
c_{ij}, the degree of harm caused by dust or toxicants No.i in factory No.j;
k, the municipal investment in harm treatment;
k_{ij}, the investment necessary to make dust or toxicants No.i in factory No.j meet the state standard;
s, the set of dust or toxicants that must be treated in at least one of the factories.

$$x_{ij} = \begin{cases} 1 & \text{means that factory No.j does treat its dust or toxicants No.i according to the state standard;} \\ 0, & \text{otherwise.} \end{cases}$$

3. Determination of the Degree of Harm by Means of AHP

Degrees of harm c_{ij} are one of the most important parameters in the mathematical model for harm treatment programming. The degree of harm acts as the first hierarchy level. There are 23 sorts of dust and toxicants under consideration. They are grouped into four clusters, of which the second hierarchy level is make up. The four sorts of dust fall in one cluster, while the rest 19 toxicants are subdivided into three clusters according to their toxic degrees. The third level consists of the specific 23 sorts of dust and toxicants. As shown in the figure 1, the lowest level has the five factors described earlier.



G
Degree of harm
dust
Three clusters of toxicants
A1
A2
A3
A4
B11
B12
B13
B14
B21
B22
B23
B24
B25
B26
B27
B31
B32
B33
B34
B35
B36
B37
B41
B42
B43
B44
B45
23 dust and toxicants
C1
C2
C3
C4
C5
Five factors

Figure 1

To give the pairwise comparison judgment matrix is a problem to be solved by a group of experts. We shall use the following method to obtain the unique judgment matrix on the basis of gathering and unifying the experts' opinions.

If an entry of the judgment matrix is given the same value by over 70% of the experts, the value of the entry is considered to be the last judgment value.

Otherwise, if the experts give different values $x_1, x_2, \cdots, x_m$ to an to an entry of the judgment matrix, we shall first find the solution x^* to the problem

$$\text{Min } \tilde{w} = \sum_{i=1}^{m} (x_i - x)^2 \tag{5}$$

and then solve the problem

$$v_k^* = \text{Min } \{|x^* - v_j|\Big|_{v_j=1,2,\cdots,9,\frac{1}{2},\frac{1}{3},\cdots,\frac{1}{9}}\}. \tag{6}$$

The results of numerical experiments show that consistency of the judgment matrices is considerably satisfactory.

The weights of the five factors of the lowest level have been obtained:

d_1 (of supernormal multiple),

d_2 (of the number of victims),

d_3 (of the ratio of the number of people under supervision to the number of victims),

d_4 (of the number of the sick),

d_5 (of the number of the dead).

Most of the experts and experienced workers we consulted are satisfied with the results above.

The c_{ij} computing procedure is as follows:

$$L_i^{(k)} = \sum_j l_{ij}^{(k)}, \qquad k=1,2,3,4,5 \tag{7}$$

$$u_{ij}^{(k)} = \frac{l_{ij}^{(k)}}{L_{ij}^{(u)}}, \qquad k=1,2,3,4,5 \tag{8}$$

$$c_{ij} = \sum_{i=1}^{5} d_k u_{ij}^{(k)},$$

Where $L_i^{(k)}$ denotes the sum of values of factor No.k (in all the factories) caused by dust or toxicants No.i.

$L_{ij}^{(k)}$ is the value of factor No.k (at factory No.j) caused by dust or toxicants No.i.

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References

1. Saaty.T.L. (1980) The Analytic Hierarchy Process.
   McGraw Hill Inc.
2. Shubo Xu, 1988, The Principle of The Analytic Hierarchy Process,
   Tianjin University Press