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EVALUATING THE KEY FACTORS FOR THE DYNAMIC EMERGENCY ESCAPE SYSTEM IN THE HOSPITAL WARD UNIT

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Abstract

Hospitals usually establish static escape system marks. Sometimes, the exit light is on but the mass often miss the opportunity to escape due to their walking around, or the long distance from the exit, or thick smoke in the exit. With the advancement of science and technology, building a dynamic escape system can help escapees completely rely on the escape guidance system. Escapees can reach the expected safe places in accordance with this guiding system, which is a comparatively important subject. This research will address the critical factors that affect the establishment of the dynamic escape system in a hospital ward, and analyze the sequence of these crucial factors with Fuzzy-AHP. The research analysis indicates that "Hospital emergency response" is the most important factor in the second layer, followed by "staff training" as the second factor. In the third layer, "training for disaster prevention education and fire drill", "clarity of the evacuation route guidance", "organization of commanders", "Fire field dynamic information" and "nurses" are the top five important factors.

Key Words: Fire disaster, Hospital ward, Dynamic escape system, Fuzz-AHP

Introduction

Given the fact that earthquake, typhoon, medical equipment and instruments and arson may cause hospital fire, compared with other large buildings, it will be more dangerous if hospital fire happens because there are many combustibles and combustion enhancers as well as many patients with mobility difficulties or disabilities. According to previous cases, when there was a fire in the hospitable, poor preparation for evacuation and not knowing how to effectively escape in accordance with the exit sign often cause mass causalities. Therefore, when disaster happens, a correct escape route in the medical institution enables staff in the hospital to evacuate to safe areas within the golden period for rescue so as to reduce personal injuries.

According to 2010's fire statistics, analysis of fire deaths in disadvantaged includes lived-alone elderly, children who the death rate in fire accidents is about 46.4%. In the hospital most people are disadvantaged, so the hospital should pay more attention to the fire facilities.

Chu (2010) firstly investigated the field investigation of the studied hospitals, including interview, corridors of wards, fire escape circulation and rescue mode, to find out the square footage of safety containment and locations of fire escape apparatus. Secondly, was to take part in fire rescue drill of the studied hospitals. Rescue mode, fire escape circulation and the use of safety containment were observed and analyzed. Third, was to conduct surveys. The results showed that different specialties in a hospital had different needs for safety containment. Because of the action capabilities – patients in surgical specialty could walk by themselves with guarding of nursing staffs, patients in internal medicine could not - the differences and needs in each specialty had to be take into account of design of the safety containment to avoid putting patients in danger.

Liao (2012) focuses on the hospital fire evacuation facilities, safety and right escape indication, combined with the interior design, lighting, and intelligent sensor devices. Guide the trapped patients escape quickly, furthermore, provide information for interior designers and architects to plan the hospital fire facilities. Hope it can be used in any types of construction in the future.

Hospitals usually establish static escape system marks (Figure 1). Sometimes, the exit light is on but the mass often miss the opportunity to escape due to their walking around, or the long distance from the exit, or thick smoke in the exit. With the advancement of science and technology, building a dynamic escape system can help escapees completely rely on the escape guidance system (Figure 2). Escapees can reach the expected safe places in accordance with this guiding system, which is a comparatively important subject.

In this study, the application of the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) for evaluating the key factors to the dynamic escape system in a hospital ward, and analyze the sequence of these crucial factors with

Figure 1. Static escape system for hospital.

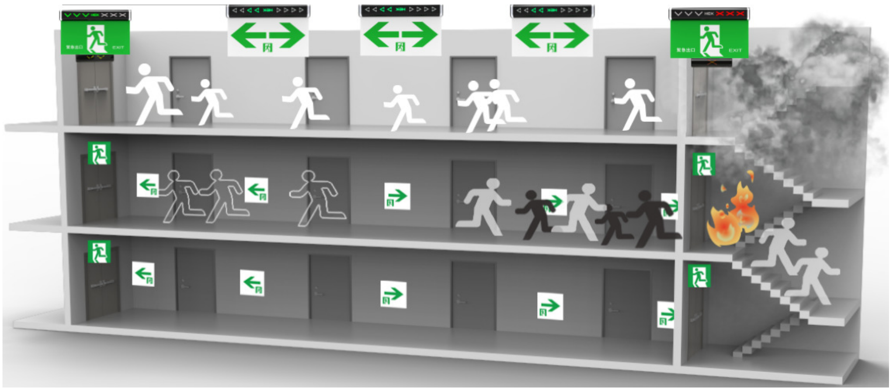

Figure 2. A dynamic escape system for hospital.

Fuzzy-AHP. The Fuzzy AHP was conducted to rank the importance and identify the key factors of the dynamic escape system in a hospital ward.

Fuzzy analytic hierarchy process

The Analytic Hierarchy Process (AHP) developed by Saaty (1980) has been widely used for multi-criteria decision-making and practical decision-making problems. In spite of its popularity, this method has been criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-maker's perception to exact numbers (Deng, 1999).

In the conventional formulation of the AHP, human's judgments are represented as exact numbers (or crisp, according to the fuzzy logic terminology). However, in many practical cases the human preference model is uncertain. Thus, decision-makers might be reluctant or unable to assign exact numerical values to the comparison judgments. Therefore, a Fuzzy Analytic Hierarchy Process (Fuzzy AHP) is used on each factor to determine the weight of fuzziness of its attributes. Herein, we apply the Fuzzy

AHP to find the importance sequence and identify the key success factors for the selection of appropriate OWES sites in Taiwan.

In the problem of decision making, the following main steps are taken for the AHP:

1. Problem hierarchically structuring: The AHP decision problem is structured hierarchically at different levels. Each level consists of a finite number of decision elements. The top level of the hierarchy represents the overall goal, while the lowest level is composed of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria.

2. Development of judgment matrices by pair-wise comparisons: The judgment matrices of criteria or alternatives can be defined from the reciprocal comparisons of criteria at the same level or all possible alternatives. Pair-wise comparisons are based on a standardized evaluation schemes from 1 to 9.

3. Assessment of global priorities: Several methods for deriving local priorities (i.e. the local weights of criteria and the local scores of alternatives) from judgment matrices have been developed, such as the eigenvector method (EVM), the logarithmic least squares method (LLSM), the weighted least squares method (WLSM), the goal programming method (GPM) and the fuzzy programming method (FPM), as summarized by Mikhailov (2000). Consistency check should be implemented for each judgment matrix.

4. Calculation of global priorities: The last step of the AHP aggregates all local priorities from the decision table by a simple weighted sum. The global priorities thus obtained are used for final ranking of the alternatives and selection of the best one.

In this study the triangular fuzzy numbers will be adopted. A triangular fuzzy number $\tilde{N}$ is defined by three real numbers ($\ell \le m \le u$), and characterised by a linear piecewise continuous membership function $\mu_{\tilde{N}}(x)$ of the type.

$$\mu_{\tilde{N}}(x) = \begin{cases} (x-\ell)/(m-\ell) & , \ell \le x \le m \\ (u-x)/(u-m) & , m \le x \le u \\ 0 & , \text{otherwise} \end{cases} \quad (1)$$

where *l*, *m* and *u* are also considered as the lower bound, the mean bound, and the upper bound, respectively. The fuzzy number $\tilde{N}$ is often expressed as a triplet (*l*, *m*, *u*).

After pair-wise comparisons are finished at a level, a fuzzy reciprocal judgment matrix $\tilde{A}$ can be established as.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{12} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & . & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} \quad (2)$$

in which *n* is the number of the related elements at this level and $\tilde{a}_{ji} = 1/\tilde{a}_{ij}$.

After constructing $\tilde{A}$, we use the fuzzy geometric means to derive fuzzy priorities $\widetilde{w}_i$, $i = 1,2,...,n$, in this paper. Finally, the global priorities expressed as fuzzy numbers can be determined by aggregating fuzzy local priorities in the following:

$$\overline{W} = \prod_{i=1}^{n} \overline{W_i} \tag{3}$$

where n is the number of level and $\prod_{i=1}^{n} \overline{W_i}$ is the product of weights for all levels.

Conceptual model for Evaluating the key factors to the Dynamic Escape System in a Hospital Ward

Although safety containment in hospitals is designed according to the building codes in Taiwan, there is a lack of considerations of different patients' physical conditions, suitable fire escape apparatus and whether there is sufficient space in the safety containment. Moreover, if the planning of the architectural safety containment does not work together with the rescue policy of a hospital, rescue would not be achieved effectively, fire escape facilities would be useless, and fire rescue drill would be a waste of time. Do fire escape facilities and safety containment meet the needs of patients? Do nursing staffs help patients correctly and fast enough when fire occurs? What are nursing staffs' knowledge of rescue mode, fire escape circulation and safety containment?

A conceptual model of evaluating the key factors to the dynamic escape system in a hospital ward is established on the basis of the Delphi method and the Fuzzy AHP method. Four main criteria have been chosen for Hospital emergency response, Patient and care evacuation, Equipment maintenance management and Staff training, and each main criterion is additionally divided into four sub-criteria, namely Emergency organization system integrity, Training for disaster prevention education and fire drill, Clarity of the evacuation route guidance, Fire field dynamic information, Degree of cooperation, Identify hidden dangers, Escape education, Assisting in fire disaster relief, Regular Simulate dynamic escape routes , Regular equipment maintenance, Self-test equipment failure, Maintenance cost and manpower, Doctors, Nurses, Administration staff and Organization of commanders. The goal here is to select the key factors of evaluating the key factors to the dynamic escape system in a hospital ward, satisfying all criteria in the best way.

The solution process is based on the proposed fuzzy modification of the AHP method. The first step in applying the fuzzy AHP is to construct a (four level) hierarchy of evaluating the key factors to the dynamic escape system in a hospital ward and criteria for choice, as shown on Figure 3.

An important consideration in terms of the quality of the ultimate decision relates to the consistency of judgments that the decision maker demonstrated during the series of pair-wise comparisons. The consistency ratio (*C.R.*) is a measure of the consistency of pair-wise comparison judgments, which measure the degree of consistency among the pair-wise judgments provided by the decision maker. If the degree of consistency is acceptable, the decision process can be continued. On the other hand, if the

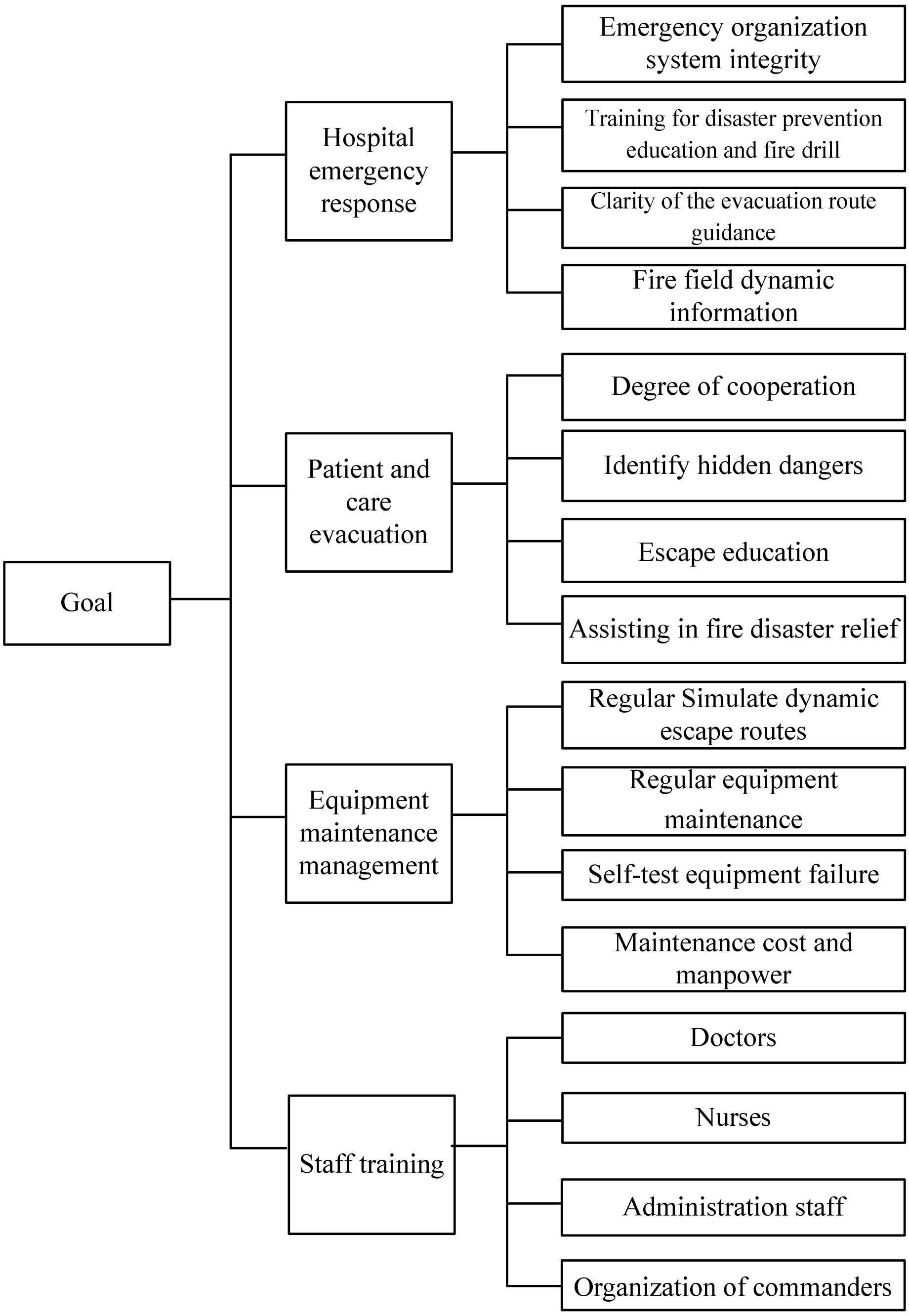

Figure 3. Decision hierarchy.

degree of consistency is unacceptable, the decision maker should reconsider and possibly revise the pair-wise comparison judgments before processing the analysis. In general, the ratio is designed in such a way that values of the ratio exceeding 0.10 are indicative of inconsistent judgments. The *C.R.* is estimated as the following:

Step 1: Multiply each value in the first column of the pair-wise comparison matrix by the relative priority of the first item considered. Same procedures will be applied to other items. Sum the values across the rows to obtain a vector of values labeled "weighted sum".

Step 2: Divide the elements of the vector of weighted sums obtained in Step 1 by the corresponding priority value.

Step 3: Compute the average of the values computed in Step 2. The λ_{max} is maximum Eigen value of the comparison matrix.

Step 4: Compute the consistency index (*C.I.*):

$$C.I. = \frac{\lambda_{max} - n}{n - 1} \quad (4)$$

where *n* is the number of items.

Step 5: Compute the consistency ratio (*C.R.*):

$$C.R. = \frac{C.I.}{R.I.} \quad (5)$$

where *R.I.* is the random index, which is the consistency index of a randomly generated pair-wise comparison matrix.

Results and Discussions

The fuzzy comparison judgments of the four main criteria with respect to the overall goal are shown in Table 1.

Hospital emergency response is regarded as the most important criterion. Utilizing the fuzzy prioritization

method, the exact weights value of main criteria is obtained as shown in Table 2.

As shown in Table 2, the value of the consistency index (*C.I.*) is 0.08 and the consistency ratio (*C.R.*) is 0.09. Both *C.I.* and *R.I.* values are much smaller than 1, which indicates that the degree of consistency is acceptable. The fuzzy weights of the comparison judgments regarding the goal are also shown in Figure 4.

Table 1. Fuzzy comparison matrices at the first level.

Goal	Hospital emergency response	Patient and care evacuation	Equipment maintenance management	Staff training
Hospital emergency response	1.000,1.000,1.000	1.961,2.858,4.082	0.727,1.061,1.640	1.200,1.779,2.726
Patient and care evacuation	0.245,0.350,0.510	1.000,1.000,1.000	0.701,0.968,1.418	0.821,1.255,1.775
Equipment maintenance management	0.610,0.942,1.375	0.705,1.033,1.427	1.000,1.000,1.000	0.395,0.511,0.725
Staff training	0.367,0.562,0.833	0.563,0.797,1.218	1.379,1.956,2.531	1.000,1.000,1.000

Table 2. The weight value of main criteria.

Goal	weights	Ranking
Hospital emergency response	w1 = 0.37	1
Staff training	w2 = 0.23	2
Equipment maintenance management	w3 = 0.20	3
Patient and care evacuation	w4 = 0.19	4

*C.I.= 0.08 ; C.R.= 0.09.

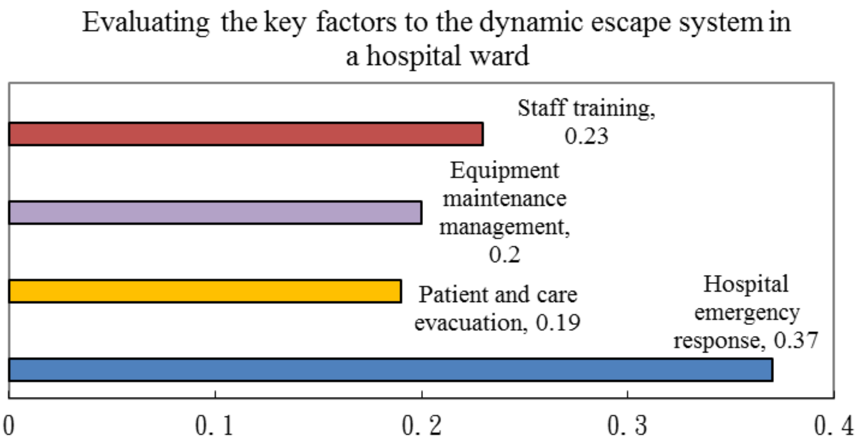

Figure 4. Fuzzy weight of the pair-wise comparisons in the main criteria.

From the Figure, Hospital emergency response is assessed as the more important issues than Staff training, Equipment maintenance management and Patient and care evacuation. Therefore, Hospital emergency response is considered as the most important criterion, since all fuzzy weight is greater than other factors.

The second level of hierarchy with respect to the upper level elements, the local fuzzy weights of the sub-criteria are shown from Figure 5~8.

In Figure 5, we can found that Training for disaster prevention education and fire drill is the most important factor comparing with Clarity of the evacuation route guidance, Fire field dynamic information and Degree of cooperation. Above results implies that Training for disaster prevention education and fire drill will help the dynamic escape system in a hospital ward.

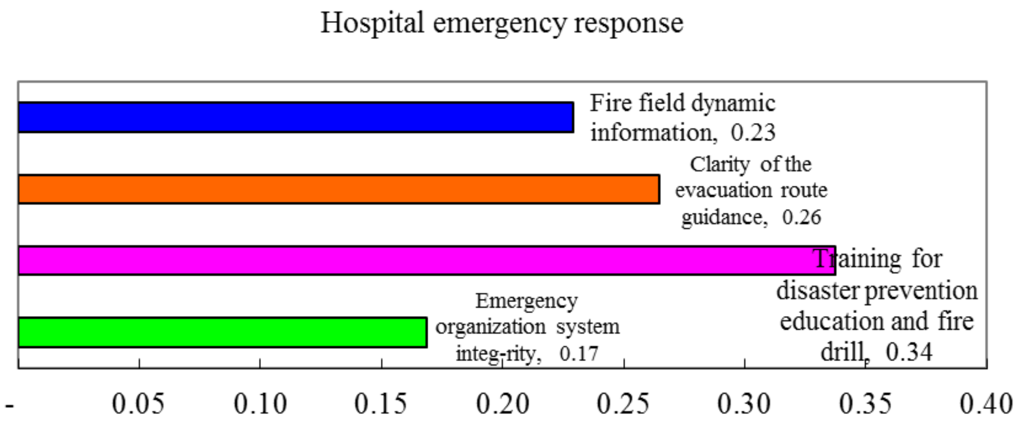

Figure 5. Local fuzzy weight of the sub-criteria for Hospital emergency response

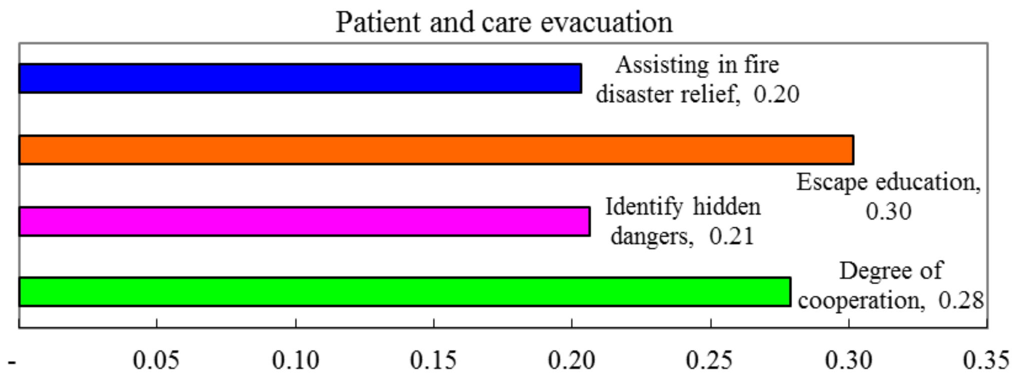

Figure 6. Local fuzzy weight of the sub-criteria for Patient and care evacuation

As for the results of local fuzzy weight of the sub-criteria for Patient and care evacuation (Figure 6), it is found that Escape education is greater than other factors. At the level of hierarchy with Equipment maintenance management (Figure 7), we can see Regular Simulate dynamic escape routes is the most important factor.

Figure 8 shows that Organization of commanders is more important than Nurses, Doctors and Administration staff.

Conclusion

This paper is aimed to address the critical factors that affect the establishment of the dynamic escape system in a hospital ward, and analyze the sequence of these crucial factors with Fuzzy-AHP. The research analysis show that the five key factors are “Training for disaster prevention education and fire drill”, “Clarity of the evacuation route guidance”, “Organization of commanders ”, “Fire field dynamic information ” and “Nurses” respectively.

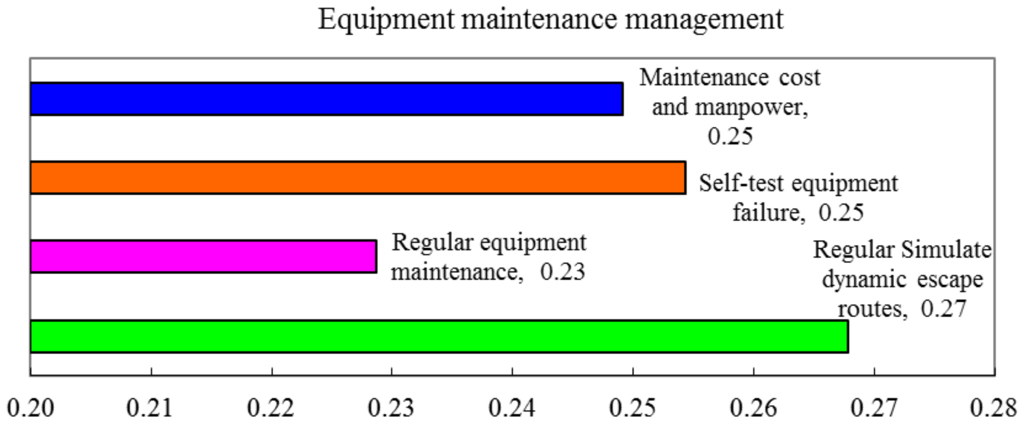

Figure 7. Local fuzzy weight of the sub-criteria for Equipment maintenance management

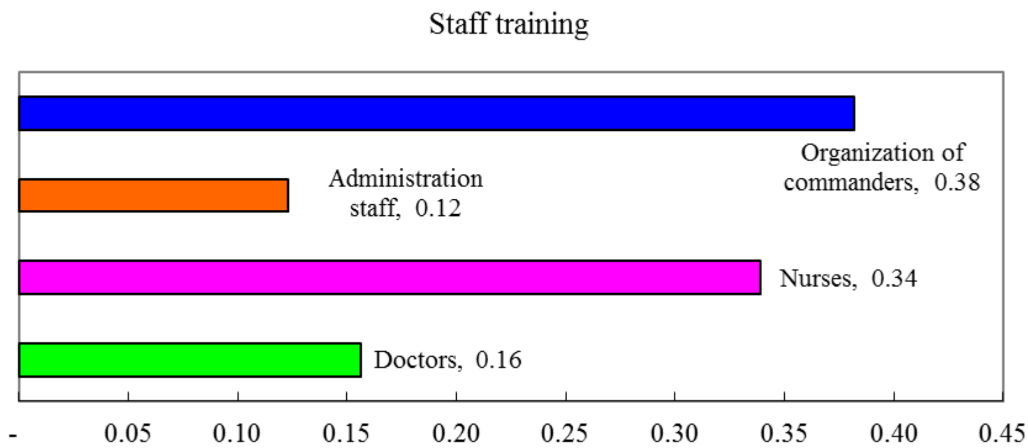

Figure 8. Local fuzzy weight of the sub-criteria for Staff training

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