Functional Performance Evaluation of Hospital Radiology Facilities and Equipment Using FA and AHP: A Case Study

Wei Tong Chen 1, Theresia Avila Bria 2, Hsieh Shih-An 3, Ferdinand Liem 2

1 Graduate School of Engineering, Science and Technology/Dept. of Civil & Const. Engineering, National Yunlin University of Science and Technology, Taiwan
2 Graduate School of Engineering, Science and Technology, National Yunlin University of Science and Technology, Taiwan / Department of Civil Engineering, State Polytechnic of Kupang, Indonesia
3 Chia-Yi Christian Hospital, Taiwan

chenwt@yuntech.edu.tw

Abstract. Result of evaluates the usage function at radiology facilities and equipment based on the professional opinions of radiology department relevant medical personnel in Taiwan, using of factor analysis (FA), analytic hierarchy process (AHP), and simple weight method is: The among the four evaluation dimensions for the usage function evaluation model of radiology facilities and equipment, the safety equipment dimension is far more important than the other so that needs to be improved (The total number of institutions, whose evaluation score falling below the dimension average value, are 9, 4, 7 and 5, respectively). Of the 17 medical institutions, the overall performance of the best (90.95) and the worst (61.47) the gap between is up to 47%.

1. Introduction

Medical personnel have 8-12 hours a day in the medical building using the medical environment, that shows importance of the hospital environment to medical staff. Medical and nursing staff and visitors depend on the performance of the hospital building to increase their productivity and to protect them from diseases and sickness [1]. The main problem at this time is the standard hospital building design model that is available, cannot meet the expectations of medical workers, so the designers are considered not professionals. [2]. Nowadays has enabled the medical buildings to provide emergency, outpatient and inpatient of the three major medical groups for high-tech medical services. Medical imaging (radiology department) to be joint relationship department for three medical groups (Figure 1). The radiology department's job is to serve imaging examinations to protect medical personnel and patients from infection and reduce cross-infection in the hospital [3]. Every Department in hospital area have many positive and negative complain about situation, room and staff behaviour [1].

This study explores the functions and needs about division of medical imaging in the medical building, from the viewpoint of relevant medical personnel in the medical imaging. The used evaluation model to assess the usage function performance of the medical imaging department. Function According to SAVE International's Glossary of Value Methodology Terms (2019) [4], 'function' is project, product, or process must do to make it work and meet the customer's needs. Function is expressed in a two-word active verb and measurable noun structure. The evaluation results of the medical imaging department are transformed into a simple benchmark for the functional
design and providing reference for the future construction of the medical buildings by the medical groups and the design of architects.

![Figure 1. The relationship among Hospital Departments](image)

2. Previous Studies
There are differences in environmental parameters before and after the hospital is occupied by patients and staff by tracing important factors that affect the dynamics of the building in the hospital environment where these factors can affect patient health and the continuity and spread of health care-related infections [5]. According to Mustafa [6], 88% of building performance attributes are highly correlated with user satisfaction. The performance-based design approach requires different attitudes and ways of thinking in designing buildings because performance-based buildings are primarily concerned with what the building must do for its owners and users.

Bobrow and Thomas [7] proposed the main design considerations for the workflow of the medical imaging department and required for the cooperative the usage function of the ancillary space and its supporting space. The designed and shielded x-ray imaging room is important for the radiation protection of the patient, staff and the general public and minimizing radiation dose to levels as low as reasonably.

3. Developing the Proposed Model
3.1 Research Tools and Analysis Methods
This study conducted a two-phase questionnaire survey to collect research data on related medical personnel of radiology department in Taiwan’s 30 medical institutions. First, the Factor Analysis (FA) and the second is Analytic Hierarchy Process (AHP) and SWM.

3.2 Building the Evaluation Dimensions
The phase-1, with 3 dimensions of space function, facility function, and environmental function. There are 62 initial evaluation items (EI)) were set as the phase-1 questionnaire variables. The five point Likert Scale was used to rate these EIIs based on respondent’s perception.

According to Stevens [8], the total number of survey samples, when applying FA, should be at least five times the number of questionnaire variables. Maximal questionnaire should be distributed to 310 respondents at least. The Exploratory FA was used to verify it. In this study, we will reduce 62 questionnaire variables via FA to extract the most explanatory factors. The total of 741 first stage questionnaires was sent and 489 copies were collected, with a return rate of 66%. The collected data were analysed to extract deep information.

Before performing the FA, it is necessary to check whether the collected data is suitable for FA or not used KMO (Kaiser-Meyer-Olkin Measure of Sampling Adequacy) and Bartlett's Test of Sphericity.
to test the suitability of FA. The KMO coefficient value from sampling is 0.952, the total variance explained sums of squared loadings value reached 68.24%, indicating that the data structure is suitable for factor analysis [9]. In addition, the Chi-square value obtained by the "Bartlett's Ball Test" is 5267.325 (degrees of freedom 435), and the corresponding p-value is 0.000 shown the correlation matrix between the questionnaire items, is suitable for factor analysis.

Secondly, the principal component analysis (PCA) to extract the four components through FA as shown in based on the common characteristics of items each dimension, were named as safety equipment (including 11 factors), basic facility (including 5 factors), spatial configuration (including 5 factors) and surrounding environment (including 3 factors).

3.3 Related Weights of Dimensions and Items
The second stage questionnaire (a total of 210 questionnaires were sent, 148 were collected, the recovery rate was 70.48%) aims at the respondents of the first stage questionnaire, which was based on the results of the factor analysis in the previous stage to:
1. Calculation of questionnaire hierarchical dimension weights: Three parts including the establishment of pairwise comparison matrix, calculation of eigenvectors (i.e. weight value) and consistency verification (including C.I. and C.R.), to determine the validity of the questionnaire. Using MS Excel with the calculation worksheet written by this study to calculate 148 questionnaires collected in the second stage of the questionnaire, the results are a total of 140 copies passed the consistency verification.
2. Calculation of overall hierarchical weights: The overall hierarchical weights are calculated for the 140 valid questionnaires which passed the consistency verification, the total average weight value of each evaluation dimension
3. Calculation of evaluation item hierarchy weights. Each number reflects the degree of importance for the respondent to the evaluation item. Since there are deferent items at the process evaluation at the evaluation criteria layer, considering that (1) when humans in comparing more than seven items, the misalignment will occur [10] and (2) the linguistic classification scale of the human ability to distinguish the message level is 7 ± 2 confirming that the weight of the third level evaluation item layer is not suitable for using the hierarchical analysis method. The weights of evaluation items are calculated according to equations, the weight values of evaluation dimension s and evaluation items obtained through the AHP and the pairwise comparison matrix.

After analysing the KMO and Bartlett sphericity test of the first stage questionnaire, the results show that the correlation coefficient is suitable for factor analysis. In the second stage, with consider the rationality of analytic hierarchy and pairwise comparison matrix logic.

4. Application of the Proposed Model
4.1 Evaluation Case Study Description
The developed evaluation model to evaluate for the usage function of the radiology department facilities and equipment in 17 medical institutions. The evaluation of the usage function is performed by radiologists from the radiology department of the medical institutions. The evaluation item score is obtained by multiplying the item weight with actual use of satisfaction score; The score of the evaluation dimension is the total sum of the scores under the evaluation items; the total score of the overall evaluation is the sum of the weight values of the four evaluation dimensions multiplied by the score of the four evaluation dimensions.

4.2 Overall Comprehensive Analysis
From this study summarized the results of the evaluation of 17 health institutions, after a comprehensive statistical analysis from various perspectives was found the phenomena according to the description in Table 1 are as follows:
1. Overall Performance
The overall performance gap of usage function by radiology department in medical institutions of Taoyuan district is the largest, and Kaohsiung district is the smallest. The performance deviation of usage function in the different dimensions of various hospitals is very large, showing these medical institutions is very poor.

2. Safety Equipment Dimension
There are 11 medical institutions with scores below the average, the usage function of safety equipment dimension needs to be strengthened. The performance of safety equipment dimension in radiology department of medical institutions in Taipei and Taoyuan districts are better than that of other regions.

3. Basic Facility Dimension
There are 6 medical institutions with scores below the average. The radiology department of medical institutions in Changhua and Taoyuan districts better than that of other regions.

4. Spatial Configuration Dimension
There are 10 medical institutions with scores below the average, the usage function of spatial configuration dimension needs to be strengthened.

5. Surrounding Environment Dimension
There are 8 medical institutions with scores below the average, the usage function of surrounding environment dimension needs to be strengthened. The performance of Taoyuan districts is the best.

Based on the evaluation cases, and according to the five-point grade evaluation results, the usage function performance of the radiology department in 17 medical institutions, provide the basis for improvement or design planning in term of the safety equipment dimension for medical usage function, "Set up radiation protection facility (including warning signs)", "Set up fireproof and soundproof ceiling", "Set up temperature and humidity monitoring system in computer room of special photography examination room" to be improved in many medical institutions; the spatial configuration dimension of the construction usage function is "the location of the moving line should be set at the shortest distance "; while the surrounding environment dimension is "Set up bathroom for staff".

### Table 1. Statistics of various dimensions and overall evaluation scores

| HP # | HP # | Location | Region | Safety Equipment | Basic Facility | Spatial Configuration | Surrounding Environment | Overall Score | Ranking |
|------|------|----------|--------|------------------|----------------|-----------------------|------------------------|--------------|---------|
| 01   | NT01 | Hualien  | North  | 72.81            | 88.19          | 76.00                 | 80.14                  | 79.29        | 7       |
| 02   | NT02 |          |        | 70.89            | 60.32          | 76.00                 | 73.46                  | 70.17        | 14      |
| 03   | NT03 | Taipei  |        | 85.65            | 91.92          | 84.09                 | 86.79                  | 87.11        | 3       |
| 04   | NT04 | Taoyuan |        | 87.51            | 92.00          | 87.90                 | 100.00                 | 91.85        | 1       |
| 05   | NT05 |          |        | 76.39            | 71.88          | 67.99                 | 60.11                  | 69.09        | 15      |
| 06   | CT01 | Taichung| Central | 71.13            | 87.98          | 76.00                 | 80.00                  | 78.78        | 8       |
| 07   | CT02 |          |        | 63.93            | 84.11          | 84.09                 | 73.46                  | 76.40        | 10      |
| 08   | CT03 |          |        | 70.91            | 87.98          | 76.00                 | 60.00                  | 73.72        | 11      |
| 09   | CT04 |          |        | 77.96            | 76.03          | 80.00                 | 80.00                  | 78.50        | 9       |
| 10   | CT05 | Changhua|        | 72.67            | 92.16          | 92.10                 | 86.67                  | 85.90        | 4       |
| 11   | CT06 | Yunlin  |        | 63.99            | 76.13          | 71.88                 | 73.46                  | 71.37        | 13      |
| 12   | ST01 | Chiayi  | South  | 72.69            | 80.00          | 96.00                 | 80.00                  | 82.17        | 6       |
| 13   | ST02 |          |        | 80.35            | 84.11          | 100.00                | 86.92                  | 87.85        | 2       |
| 14   | ST03 |          |        | 59.63            | 39.93          | 72.02                 | 80.25                  | 62.96        | 16      |
| 15   | ST04 | Tainan  |        | 72.66            | 83.87          | 76.00                 | 60.00                  | 73.13        | 12      |
| 16   | ST05 | Kaohsiung|        | 65.58            | 68.19          | 52.10                 | 60.00                  | 61.47        | 17      |
| 17   | ST06 |          |        | 85.18            | 91.95          | 92.10                 | 66.54                  | 83.94        | 5       |

Total Average | 73.53 | 79.81 | 80.02 | 75.75 | 77.28 |
4.3 Usage Function Analysis
This study utilized functional analysis techniques of VE to identify the functional areas to be improved is:

1. Safety Equipment Dimension
   Set up radiation protection facility. This function can be improved by strengthening radiation protection facilities and warning signs.

   "Set up fireproof and soundproof ceiling" is designed to block noise and heat, the radiology department only by setting up fireproof and soundproof ceilings to providing a comfortable medical environment. "Set up temperature and humidity monitoring system in computer room of special photography examination room" to provide safe and stable medical equipment. This function can be improved through the installation of temperature and humidity monitoring system.

2. Space Configuration Dimension for Building Usage Function

   "The location of the moving line should be set at the shortest distance from the three major medical groups of emergency, outpatient and inpatient". With the radiology department setting up located at the shortest distance from the emergency department, outpatient department and ward, in order to facilitate the patients to do the examination. This function can be improved in emergency department outpatient department, with the addition of dedicated X-ray room.

3. Surrounding Environment Dimension

   "Set up bathroom for staff". This deficiency due to limited to the inherent structure of the radiology department, the water and electricity pipelines, the sewage system, which cannot be changed, it should be considered when the radiology department is newly built or rebuilt in the future.

5. Conclusions
From the results of the evaluation of the function of use and consideration as well as future priorities in the radiology department, it can be seen from the evaluation results with the following weight values: For the weight of safety equipment dimensions (0.4078) is the highest then, basic facility dimensions (0.2084), configuration dimensions spatial (0.1897), ambient dimension (0.1941), indicating that the radiology department requires multiple safety equipment and basic facilities to fulfill its use function. For terms. evaluation item weight, safety device dimensions prioritized with "Prepare medical gas facilities in special photographic examination room" (0.0957), basic facility dimensions are given priority with "Prepare PACS screen in reading room" (0.2054), spatial configuration dimensions are prioritized with "Set up computed tomography room" (0.2060), the dimensions of the surrounding environment are prioritized by" Set up check-in counter" (0.3394)

Result function evaluation form (100 points for full score) for each medical institution is : For a case analysis of the number of medical institutions, the overall performance of the use function is not good. The function of using safety devices and room configuration needs to be strengthened. For evaluation items the dimensions of safety equipment and the surrounding environment need to be improved. This evaluation model can be used as a reference for architects to design and plan a radiology department or medical institute for new construction, reconstruction and repair in the future and also special consideration in planning and construction should be given the location of the moving line should be set at the shortest distance of the three emergency, outpatient and inpatient main medical groups Prepare (bathrooms for staff, radiation protection facilities -including warning signs, fireproof and soundproof ceilings, temperature and humidity monitoring systems in computer rooms special photographic examination rooms, etc.).

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