Hospital Air Handling Unit Selection with AHP Method in Turkey

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Abstract: ***The paper deals with choosing of AHU for hospitals with multi-criteria decision making method in Turkey. The hospitals require heating, cooling, or both, depending on climate zones, to keep ambient conditions within a reasonable range. In hospitals, heating, cooling or both according to climate zones are required to keep the ambient conditions in an appropriate range. The provision of hygienic environments in hospitals for human health has become very important. Hygienic AHU should be used for the air conditioning and ventilation of hygienic environments. The air handling unit used in hygienic systems must have additional features compared to comfort AHU. The weights of cost, flow rate, mass, power, and noise were determined. According to the criteria AHP method was applied to obtain the most appropriate AHU for hospital.***

Keywords: hospital AHU, clean rooms, decision making, AHP method

1. Introduction

The market of the air handling unit application depends on area, type, and capacity. The AHU system market was valued at US $ 181.0 billion in 2018 and is expected to reach US $ 251.6 billion by 2023, at a compound annual growth rate of 6.80% between 2018 and 2023 [1].

World demand for air conditioning increased by 8.1% in 2017 compared to the previous year and reached 110.56 million units. Demand in Turkey 790 thousand units in 2016 and demand in 2017 was 839 thousand units [2].

Air handling unit (AHU) referred to as climate control is a process of treating air to control its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space. If the primary function of the system is to satisfy the comfort requirements of the occupants of the conditioned space, the process is referred to as comfort air conditioning.

AHU systems are also important to occupants' health, because a good regulated and maintained system will keep spaces free from mold and other harmful organisms. The term ventilation is applied to processes that supply air to or remove air from a space by natural or mechanical means.

The energy consumption of air conditioning systems is the most intense in terms of all technical building services, commercial buildings such as hospitals, office buildings and other similar buildings. Implementing a Time Control Program (TCP) using multi-state operation by resetting channel pressure values provides significant savings in energy consumption [3].

In hospitals, heating, cooling or both according to climate zones are required to keep the ambient conditions in an appropriate range. Selection of appropriate AHU to be used in hospitals is important in terms of power, air flow and other factors.

The AHU industry had been regulated by the manufacturers but regulating organizations such as ACHRI (Air Conditioning, Heating and Refrigeration Institute), AMCA (Air Movement and Control Association), ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), UMC (Uniform Mechanical Code), and IBC (International Building Code) have been established to support the industry.

The prime requirement in respect of the climate in a hospital is that room temperature should be at a comfortable level. In addition, the air must be acceptably clean, lighting and acoustic conditions must be good enough.

Thermal comfort can be defined as a subjective response, or state of mind, when a person expresses satisfaction with the surrounding environment. The environment must provide light, air, and thermal comfort.

The factors of metabolic rate, evaporation, conduction, convection, and radiation affect the physical comfort. Proper acoustics and hygiene are also important for physical comfort. While it may be partially influenced by a variety of contextual and cultural factors, a person's sense of thermal comfort is primarily a result of the body's heat exchange with the environment. This is influenced by thermal parameters; air temperature, radiant temperature, humidity and air speed and personal parameters; clothing and metabolic rate [4].

The provision of hygienic environments in hospitals for human health has become very important. Hospital infections cost $ 132 million in Norway and $ 1.7 billion in the UK.
Deaths due to hospital infections have a significant impact on the US budget. $ 1.6 billion of these expenditures consist of infections occurring in the operation area. As a result of these infections, an estimated 19 thousand people die annually in the United States. According to data from the

World Health Organization, 1.4 million people worldwide suffer from hospital infections.

In Europe, hospital infection develops in 7% of patients admitted to acute care hospitals. Deaths due to hospital infections direct death of 37 thousand people and the indirect death of 110 thousand people have led to healthcare expenditures of 7 billion Euros per year for hospital infections. In the 1970s, the National Nosocomial Infections Surveillance (NNIS) system began collecting surveillance data (surveillance, systematic collection and processing of data). In 2005, NNIS was reorganized to name the National Healthcare Safety Network (NHSN).

In Turkey, which was enacted in 1974 and only teaching hospital in the interests Medical Specialization Regulation "Infection Committee" under the title two regulations by Article enacted in 1983. Infections occurring within the first 10 days of hospitalization or 48 hours after hospital admission are accepted as Hospital Infection. Infection Control Committees were established in hospitals by the Regulation on Infectious Control of Inpatient Treatment Institutions [5].

Thus, the principles of sterilization, antisepsis and disinfection processes and the standards for the selection of disinfectants are determined. Hospital infection leads to adversities such as loss in quality of life, increased morbidity, prolonged hospital stays, loss of labor and productivity.

2. Hospital Air Conditioning

Hygienic AHU should be used for the air conditioning and ventilation of hygienic environments. The air handling unit used in hygienic systems must have additional features compared to comfort AHU. Due to the average temperature in Istanbul, hospital both heating and cooling is required in Istanbul.

Extreme maximum, minimum and average temperatures measured in long period throughout the year shown in the Table 1 [6]. Average temperature is minimum at January as 6.0°C and maximum in both July and August as 23.8°C.
The sensed temperature, unlike the actual physical air temperature measured by the thermometer, is the temperature that the human body feels. This is a subjective concept because the temperature is influenced by the four meteorological factors such as the climatic environment, heat resistance of clothing, body structure and personal condition as well as thermometer temperature, relative humidity, air circulation speed and radiation. Therefore, sensing and feeling of temperature varies from person to person.
The human body dissipates heat by changing the rate and amount of blood circulation, by losing water with skin and sweat glands, and by an increase in respiration when the body temperature rises above 37°C. The heart begins to pump more blood, the blood vessels expand to regulate increased blood flow, and the stacks of very fine capillaries begin to enter into the upper layers of the skin. The body blood circulates near the skin surface and the excess heat is thrown into the cooler ambient. At the same time, water is discharged through the skin. The skin provides 90% of the body temperature emitting function.

Table 1: Extreme Maximum, Minimum and Average Temperatures (°C) Measured in Long Period Outside Temperatures in Istanbul

Month	Jan	Mar	May	Jul	Sep	Nov
Max	22.0	29.3	34.5	41.5	39.5	27.8
Min	-13.9	-11.1	1.4	10.5	6.0	-7.2
Ave	6.0	7.7	16.7	23.8	20.1	11.7

In view of the possibility of future expansion of hospitals, AHU capacity should be chosen slightly larger than required. These features are as follows:

- Hygienic AHU should not allow particles and micro-organisms into the air conditioning cassette and have a sealed structure.
- Hygienic AHU should not allow the accumulation of particles. Therefore, the inner surfaces of the plant should be flat and the elements should not have a porous structure.
- Hygienic AHU should not allow the formation of micro-organisms. Therefore, the accumulation of water or high humidity should not be allowed on the air handling unit surfaces. All materials used must not be capable of producing microorganisms.
- Hygienic AHU should be easily cleanable. The elements inside the AHU must be reached easily for cleaning [7, 8].

Although the effects of air conditioning systems (HVAC, Heating, Ventilating, and Air Conditioning) are well known, there are great differences between the relevant standards. Hospitals have many sterile sites with high risk of infection and air conditioning systems play an important role in the risk of infection in sterile sites.

The radiation due to the lighting affects the relative comfort of the thermal humidity. In the study conducted with a two-part instantaneous energy balance model, the effect of relative humidity on skin wetness is determined to be higher than the effect on skin temperature.

The temperature distribution and flow structure in the room have changed significantly depending on the input speed and temperature. The structure of the entering air jet affects the homogeneity of the temperature distribution. When the results are examined, it is seen that a more homogeneous temperature structure is formed in the air which is blown at 2 m/s.
Heat loss is observed to be high due to the low temperature limit condition on the walls as the blowing temperature decreases. This situation affects the temperature of the air in the office at all points independent of the input speed.

If all conditions are examined and a general opinion is desired, it is possible to obtain a uniform distribution of temperature in an air conditioner with an input temperature of 30°C and an input speed of 2 m/s. Depending on the structure of the entering air jet, the temperature distribution and the flow structure vary considerably [9].

Skin and body fluids from infectious patients increase the pathogen level of microorganisms in health facilities. These pathogens can be contacted with or without contact. The HVAC system is one of the few tools used in infection control.

In many health facilities, chemical fumes, aerosols, or harmful gases that create health or safety hazards are exposed or stored. In such applications, the primary protection equipment such as the smoke hood, the radioisotope holder and the anesthetic waste drain works in conjunction with the HVAC.

Air handling and distribution systems fulfill the function of providing comfort conditions in health centers, protection of air quality, infections, odor control reduction of airborne and smoke removal. For air exchange rate, temperature, humidity and filtration, application is made according to design standards in various parts of hospitals.

2.1 Effect of AHU on Employees and Patients

During the breathing, dust enters the body with air. The nose can hold 10 μm sized dust. Powders of 5-10 μm in diameter can be retained in the upper respiratory tract. Dust with a diameter of 2.5-5 μm can be returned without entering the lungs. Powders with a diameter of 1-2.5 μm can be kept in the bronchi.

Much damage is prevented by the defense mechanism in the lungs. One miner swallowed 1000 g of charcoal powder for the rest of his life, and his medical examination showed that there were less than 40 g of dust in his lungs.

Although the lungs are self-cleaning, dusts can cause diseases [10]. For health care, HVAC must fulfill vital functions that are effective in environmental conditions, infection and control of harmful substances, and building life safety [11].

Although the effects of air conditioning systems on the infection are well known, there are great differences between the relevant standards.

Hospitals have many sterile sites with high risk of infection and air conditioning systems play an important role in the risk of infection in sterile sites.
In addition to temperature and humidity parameters, air conditioning and ventilation systems used for sterile spaces also concentrate on parameters such as number of particles, number of microorganisms, pressure differences, and air velocity. Therefore, it is also stated that air conditioning applications are more difficult in sterile environments [12].

Ensuring working and patient comfort conditions facilitates treatment. Environmental conditions for electronic data storage, support IT systems, private imaging and other medical equipment are important. In the absence of air conditioning, patients may be subject to a temperature disturbance.

In the examination rooms, patients should wear simple clothing and physicians need to work hours for an orthopedic patient.

It is recommended that intensive care units be kept at 24-27^{o}C temperature, 30-60% relative humidity and positive pressure. Sometimes it is desirable to fix the temperature at 32 °C in the treatment of hypothermia in emergency departments [13, 14]. Very low humidity causes dryness of the skin and causes the patients to malfunction.

The effects of indoor air quality on human health are the subjects of research. There is a relationship between temperature, humidity, particles and noise and hygiene. Absolute humidity is the humidity (g/m^3) in air of a unit volume at a defined pressure.

Relative humidity is the ratio of humidity in air per unit volume to saturated air at the same temperature. When the relative humidity is 5-30%, it irritates the eyes and upper respiratory tract and causes a complaint.

The temperature and humidity of the patients were measured in hospital rooms during the 3 months period and 36 patients and 45 personnel were surveyed to increase the comfort when the humidity was increased from 33% to 44%.

It was found that tear evaporation rate required 10 minutes to be smooth and tear evaporation rate was higher in patients with dry eyes [15].

The low humidity, sun exposure time, air pollution causes the eye dryness disease [16].

The microbes present in the air are seasonal in the hospital environment. The highest bacterial level is observed in the external patient section with 1649.7 CFU/m^3 and the highest fungus level is 193.4 CFU/m^3.

In microbiology, the cob unit (CFU, colony-forming unit) is used to estimate the number of live bacteria or fungal cells in a sample. In order to keep the microbe level in the air low, the cleaning frequency must be sufficient [17].

There are also national standards other than International 209E and ISO 14644-1 standards. According to national standards, the number of bacteria in France and Wales countries is 10 CFU/m^3 and Russia is 5-20 CFU/m^3 [18]. Bacteria from microbes; rods, spherical and spiral, while some fungi are harmful, but fungi such as saccharomyces cerevisiae are useful. Bacteria are 1000 nm in size. Viruses are smaller than bacteria and have a size of 20-400 nm. Fine dusts cause diseases and delay the healing of patients. Powders with a diameter of 30 μm are normally visible. Powders larger than 10 μm in diameter can be seen in light and contrast.

2.2 Types of AHU

The fan coils/fan is the smallest and the simplest type of AHU and, as the names suggest, they usually include a fan and a heat transfer serpentine. There is also a simple filter to prevent the coils from being contaminated too quickly. In general, they have a simple valve and serve a single temperature zone. Although they have applications, they are generally less efficient than larger AHU and have difficulty in providing better temperature and humidity control.

Packaged AHU is very common in small buildings and commercial applications, especially in roof units. Package units usually include fans, coils, filters and dampers in a single enclosure. Because of their compactness and low initial costs, the packaged units are renowned. Performance and reliability are high. They are available in capacities from a few 30 000 m^3/min to 900 000 m^3/min, but in some applications their standardization may be limited.

Modular AHU allows users to select individual components in modules with consistent structure and cross-sections. The user can select the type of covers, fans, filters, coils and accessories from various options. The modules are factory installed or can be individually installed and mounted on site. Modular units usually provide great flexibility and can meet most air handling requirements.

Special AHU can be used in almost all configurations that the user needs. They are generally of the highest quality and are used in institutional or industrial applications where the highest flow rates, precise control and strict conditions are present. They can also be applied in irregular areas that do not fit a modular line. In order for hospital staff and patients to work comfortably, factors such as temperature, humidity, lighting and noise should be evaluated.

The companies that produce AHU describe the technical specifications in accordance with the relevant standards in their catalogs and make the choices of the user firms according to these standards. Here a multi-criteria decision-making problem arises. Factors such as the price of the plant, air flow rate, air speed, mass, capacity and noise level complicate the selection. The use of Multi-Criteria Decision-Making methods is the easiest choice in selecting the most suitable air handling unit.

2.3 Air Cleaning Filters

Air cleaning filters remove pollutants from the air flow and significantly improve air quality. Classification systems for air filters, such as Test Methods for Airborne Discharge Efficiency by Particle Size, mean efficiency that provides a comprehensive and consistent demonstration of the capture performance of the filter.

The Minimum Efficiency Reporting Value (MERV) classes are obtained from the ASHRAE 52.2-2012 test, which divides particle sizes into three categories. Small, medium, and large particle sizes are 0.3-1.0 μm, 1.0- 3.0 μm, and 3.0-10 μm respectively (Table 2). The high MERV rating does not always mean better [19].

Table 2: Classes of Minimum Efficiency Reporting Value

MERV	Particle size of the filter, μm			Examples
	0.3-1.0	1.0-3.0	3.0-10.0	
1			<20%	pollen, dust mites, carpet fibers, spray paint powder
2			<20%	
3			<20%	
4			<20%	
5			20-34%	mold spores, hair spray, fabric protector, cement powder
6			35-49%	
7			50-69%	
8			70-85%	
9		<50%	85%	moisturizing powder, lead powder, auto emission
10		50-64%	85%	
11		65-79%	85%	
12		80-89%	90%	
13	<75%	90 %	90%	bacteria, cigarette smoke sneezing, droplet
14	75-84%	90%	90%	
15	85-94%	90%	90%	
16	95 %	90%	90%	

Energy is the biggest cost for operating a heating and air conditioning system. Having an unnecessarily higher MERV filter can result in a higher pressure drop due to filter selection and increase operating costs.

The MERV classification of the filters is a good way to evaluate the effectiveness of the filter. ASHRAE recommends a product with MERV 6 or higher, US Department of Energy, MERV 13 and LEED, MERV 8.

New classification systems, such as the European Standardization Committee EN779: 2012, are not only the ability to capture particles, but also the air filters that take into account the estimated annual energy use. A similar approach is expected in the United States in the coming years.

The life and cost of the filters should be considered carefully during the design and follow-up of the filters. In general, considering the initial cost of the filters, energy use, modification and disposal costs, the filter can have as little as 4% of the life cost of the filters. It is also extremely important that there is no redundancy on the access area. If the filters are difficult to reach for maintenance in an air handling unit, they are not easily replaced and the unit consumes excessive energy and performance is low. The International Building Code (IBC) and the International Mechanical Code (IMC) provide the requirements for equipment location, condensation disposal and minimum outside air quantity. Energy efficiency requirements for individual units and packaged units are provided in the International Energy Conservation Code (IECC), ASHRAE 90.1 and the 24th of the California Energy Commission.

Each state and territory determines the applicability of these codes and standards. The code generates significant pressure to go beyond the minimum performance. There are many tasks for federal projects that require new buildings to operate with much less energy than those with minimum code compliance. The US Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system requires new buildings to have at least 10% less energy expenditure than a code-compliant building and reward points, based on increased savings of over 10%. The International Green Building Code (IGCC) and the ASHRAE Standard 189.1 also consider the energy performance as serious and are increasingly adopted by states and regions.

Many organizations provide standards for testing, rating and installation of AHU and related components. Some examples include the Air Movement and Control Association (AMCA), the International Institute for Air Conditioning, Heating and Cooling (AHRI), ASHRAE, and Sheet Metal and Air Conditioning Contractors' National Association (SMACNA).

These organizations produce testing and rating standards that manufacturers can use to measure their performance. Although most of the technology in AHU has not been relatively unchanged for decades, relatively new components and applications have been developed that may be useful in the right application. Direct drive fans directly connect the fan and the motor.

3. Hospital Air Handling Unit Selection

The selection criteria of AHP method for the selection of hospital AHU were determined. After the criteria were determined, the relations between the criteria were obtained hierarchically. Hierarchical structure was formed for criteria and alternatives shown in Figure 1 [20, 21].

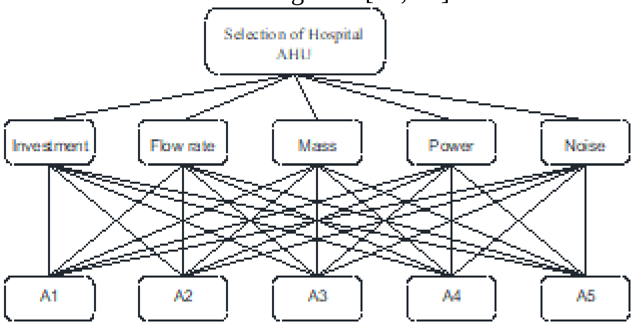

Figure 1: Hierarchical structure in the selection of hospital AHU

To select the most suitable air handling unit, paired comparison matrices were found. The features that are important in the selection of the air conditioning unit compiled from air conditioning companies are given in Table 3. Here noise level is at the frequency of 1000 Hz.

Table 3: AHU properties of various manufacturers

Company	Investment US $	Flow rate m^3/h	Mass kg	Capacity kW	Noise level, dB
A1	17000	19980	2721	38.92	53
A2	14600	21348	2735	57.07	55
A3	15000	20340	2594	39.05	54
A4	13400	23040	2832	53.31	56
A5	14000	22500	2804	55.00	56

The overall priorities will be heavily influenced by the weights given to the respective criteria. It is useful to perform a "what-if" analysis to see how the final results would have changed if the weights of the criteria would have been different. This process is called sensitivity analysis and constitutes the fifth step in our AHP methodology.

Sensitivity analysis allows us to understand how robust is our original decision and what are the drivers (i.e., which criteria influenced the original results). This is an important part of the process and, in general, no final decision should be made without performing sensitivity analysis.

3.1 Air Handling Unit Selection using AHP Method

Weights of investment, flow rate, mass, power, and noise were determined as 8, 5, 4, 7 and 8, respectively (Table 4). Each criterion may have the different importance. Therefore, the second step in the AHP process is to derive the relative priorities (weights) for the criteria. It is called relative because the obtained criteria priorities are measured with respect to each other. Pairwise comparison of the matrix of criteria is given in Table 4. K1, K2, K3, K4 and K5 respectively represent investment, flow rate, mass, power and noise criteria.

Table 4: Pairwise comparison matrix of criteria for selection the hospital AHU

	K1	K2	K3	K4	K5
K1	1.00	0.50	6.00	4.00	3.00
K2	2.00	1.00	9.00	7.00	6.00
K3	0.17	0.11	1.00	0.33	0.20
K4	0.25	0.14	3.00	1.00	0.33
K5	0.33	0.17	5.00	3.00	1.00
Sum	3.8	1.9	24.0	15.3	10.5

The selection of AHU with AHP method steps is given below. The decision-making problem is solved by taking 5 criteria and 5 different AHUs.

3.2 Pairwise Comparison Matrix of Criterion K1 for Investment

Table 5 shows the comparison of investment. It is suitable because the random consistency ratio is less than 0.10.

Table 5: AHU comparison matrix of criterion K1 of investment

	A1	A2	A3	A4	A5	W	A*W	D= A*W/W
A1	0.040	0.038	0.041	0.041	0.040	0.040	0.201	5.0060
A2	0.197	0.186	0.192	0.183	0.186	0.189	0.931	4.9309
A3	0.124	0.124	0.128	0.127	0.133	0.127	0.639	5.0272
A4	0.361	0.372	0.371	0.367	0.362	0.367	1.835	5.0025
A5	0.277	0.279	0.268	0282	0.279	0.277	1.394	5.0280
	λ_{max}	5.000	CI	0.000	CR	0.000		

3.3 Pairwise Comparison Matrix of Criterion K2 for Flow Rate

Table 6 shows the comparison of flow rate. It is suitable because the random consistency index is less than 0.10.

Table 6: AHU comparison matrix of criterion K2 of flow rate

	A1	A2	A3	A4	A5	W	A*W	D= A*W/W
A1	0.052	0.052	0.049	0.053	0.052	0.052	0.260	5.056

A2	0.151	0.151	0.144	0.153	0.149	0.150	0.755	5.048
A3	0.073	0.072	0.068	0.069	0.065	0.069	0.342	4.929
A4	0.469	0.468	0.472	0.475	0.481	0.473	2.375	5.021
A5	0.255	0.257	0.267	0.250	0.253	0.256	1.266	4.938
	λ_{max}	4,999	RI	0.000	CR	0.000		

3.4 Pairwise Comparison Matrix of Criterion K3 for Mass

Table 7 shows the comparison of mass. It is suitable because the random consistency ratio is less than 0.10.

Table 7: AHU comparison matrix of criterion K3 of Mass

	A1	A2	A3	A4	A5	W	A*W	D= A*W/W
A1	0.133	0.130	0.129	0.141	0.127	0.132	0.666	5.043
A2	0.146	0.143	0.141	0.147	0.138	0.143	0.715	5.0012
A3	0.042	0.041	0.040	0.039	0.040	0.040	0.201	4.967
A4	0.333	0.343	0.361	0.353	0.364	0.351	1.763	5.025
A5	0.346	0.343	0.329	0.320	0.331	0.334	1.654	4.952
	λ_{max}	4.998	CI	-0.001	CR	0.000		

3.5 Pairwise Comparison Matrix of Criterion K4 for Capacity

Table 8 shows the comparison of capacity. It is suitable because the random consistency ratio is less than 0.10.

Table 8: AHU comparison matrix of criterion K4 of capacity

	A1	A2	A3	A4	A5	W	A*W	D= A*W/W
A1	0.044	0.045	0.044	0.045	0.043	0.044	0.221	4.9970
A2	0.398	0.406	0.412	0.404	0.407	0.406	2.031	5.0059
A3	0.049	0.048	0.049	0.049	0.049	0.049	0.243	4.9885
A4	0.159	0.162	0.160	0.162	0.162	0.161	0.809	5.0232
A5	0.350	0.338	0.335	0.340	0.339	0.340	1.696	4.9836
	λmax	5.000	CI	0.000	CR	0.000		

3.6 Pairwise Comparison Matrix of Criterion K5 For noise

Table 9 shows the comparison of noise. It is suitable because the random consistency ratio is less than 0.10.

Table 9: AHU comparison matrix of criterion K5 of noise

	A1	A2	A3	A4	A5	W	A*W	D= A*W/W
A1	0.042	0.043	0.043	0.042	0.042	0.043	0.212	4.9724
A2	0.148	0.152	0.152	0.152	0.152	0.151	0.758	5.0189
A3	0.047	0.047	0.047	0.047	0.047	0.047	0.237	5.0145
A4	0.381	0.379	0.379	0.379	0.379	0.380	1.897	4.9969
A5	0.381	0.379	0.379	0.379	0.379	0.380	1.897	4.9969
	λ_{max}	5,000	CI	0.000	CR	0.000		

According to the Table 10 the most appropriate alternative is A4.

Table 10: Ranking of decision alternatives

	Investment	Flow rate	Mass	Capacity	Noise	Criteria w	Normalized	R
A1	0.040	0.052	0.132	0.044	0.043	0.265	0.049	5
A2	0.189	0.150	0.143	0.406	0.151	0.491	0.178	3
A3	0.127	0.069	0.040	0.049	0.047	0.037	0.079	4
A4	0.367	0.473	0.351	0.161	0.380	0.073	0.405	1
A5	0.277	0.256	0.334	0.340	0.380	0.135	0.287	2

4. Conclusion

MCDM methods, examining existing alternatives according to deterministic criteria values, leads to the best compromise solution and as a result the decision maker can sort, group, or select from existing alternatives. Within the scope of this study, the problem of choice of hospital air handling unit was taken into consideration and a systematic approach was followed in the solution of the problem. AHP method was used to determine the weight of the criteria affecting the selection. AHP method has been used in medical decision-making process in many areas such as diagnosis, patient participation, treatment, organ transplantation, evaluation of project-technology and selection, human resource planning, health care and evaluation of policies. These areas of use of AHP method show the strength of the method as an assessment tool [22]. It was determined by the surveys that the results related to the amount of investment, air flow, mass, cooling capacity and noise level of the air conditioner were more influential in the decision-making process. In the hospitals, there are many negative situations in the medium term, where the selection process is not properly managed, the overhead of the operation and maintenance costs, and the insufficient quality of service. It is thought that the conceptual framework and systematic approach found by this study can be used in the selection process of air handling unit which is a time-consuming and critical process for many health institutions. In addition, the use of appropriate methods and the involvement of the relevant experts in the process of obtaining the MCDM technology to improve patient care, investments and risks are taken under control. According to the AHP method, the interaction between the criteria was evaluated and the paired comparison matrices were formed and the weights of the criteria were determined.

According to the survey results, the initial investment costs are important in a new system. Furthermore, the noise is not desired in the hospital and it has the highest weight in the decision-making process. Moreover, cooling capacity is immediately followed by noise. The cooling capacity is important to meet the additional loads that will arise when the plant is expanded. These are followed by investment, air flow and mass. The plant mass is required for ease of transport and installation. The mass of the unit has the lowest mass compared to the other criteria.

The weight score w, which is in the pairwise comparison of the A1, A2, A3, A4 and A5 options according to a certain criterion by the AHP method, is based on a comparison of the values of the options physically and each of them shows the relative results.

In the pairwise comparison of investment options, it is the A4 air handling unit with the largest value as w = 0.367. This investment amount is US $13400 with the A4 air handling unit and the result is logical. It is the A4 air handling unit with the largest value in w = 0.475 for the pairwise comparison of the flow rate options. This result is also reasonable as the A4 air handling unit provides the maximum air flow. It is the A3 air handling unit with the smallest value w = 0.040 in the pairwise comparison of the options in terms of mass. As the A3 air handling unit has the smallest mass, the result is correct. In terms of capacity, pairwise comparison of the options is A2 air handling unit with the highest value of w = 0.406. Since the highest capacity has an A2 plant, the result is reasonable. In the pairwise comparison of the options in terms of noise, it is the A3 air handling unit with the smallest value as w = 0.042. The result is true since the lowest noise level is at the A1 plant. These are the relative values found in the pairwise comparison of the A1, A2, A3, A4 and A5 options with the AHP method.

The actual rankings of the options emerge when the criteria included in the benchmark evaluation are treated with the weight vector. The superiority of the criteria K1, K2, K3, K4 and K5 compared to each other, or weight factors, is based on survey studies. The weight factors of the criteria were found to be 0.265, 0.491, 0.037, 0.073 and 0.135, respectively. As a result, according to AHP method, the normalized final values of alternatives A1, A2, A3, A4, and A5 are 0.0497, 0.1785, 0.0791, 0.4052 and 0.2875 respectively. Hence the first choice is A4 air handling unit with a normalized value of 0.4052. The least suitable air handling unit is A1 air handling unit with a normalized value of 0.0497.

To determine the weights of the criteria in the TOPSIS method, a method such as 1 to 5 or a score scale from 1 to 9, or a method such as SWARA, AHP and ENTROPI can be used. With the TOPSIS method, the sorting result found with AHP was found in the order of the options. In this study, the results obtained by TOPSIS method are fully compatible with the results obtained by AHP method.

The results of the survey used in this study do not take into account the effect of operating costs and maintenance costs. In a later study, the consideration of the issue in this respect will ensure that investment and operating costs are seen together.

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