Anbar Journal Of Engineering Science©Vol 7(2019) 399 – 407

Unviersty of Anbar

Anbar Journal Of Engineering Science©
journal homepage: http:// http://www.uoanbar.edu.iq/Evaluate/

Decision Making in Materials Selection: an Integrated Approach with AHP

Sattar A. Mutlag[a*] and Hamad M. Hasan [a*]

[a] *Department Mechanical Engineering, Al-Anbar University, Ramadi-Iraq*,

PAPER INFO

Paper history:
Received 18 Mar 2019
Received in revised form … … …
Accepted 09 Jun 2019

Keywords:
Analytic hierarchy proces (AHP), material selection, decision-making, Air Condition, Multi-criteria.

ABSTRACT

Materials selection is a multi-criteria decision-making (MCDM) problems because the large number of factors affecting on decision making. The best choice of available material is critical to the competitiveness and success of the manufacturing organisation. The analytical hierarchy process (AHP) is an important tool to solve MCDM problems. The choosing process of suitable material (such as a refrigerant fluid) for the Air Condition System (ACS) is faced with challenges such as lack of a systematic approach in setting the optimal performance in terms of its impact on the environment and operation. Selecting process for the one refrigerant from a range suitable of suitable refrigerant is complex process. The study presents a comparative performance analysis of ACS for using four alternative refrigerants R290, R410, R404 and R22. Then, one of these suitable refrigerant is selected. The comparison is based on three criteria system operation, environment and maintenance.

Novels ACS performance assessment model is proposed based on an analytical hierarchy process (AHP). The model is based on two main criteria of ACS, quantitative criteria, cooling capacity (CC), coefficient of performance (COP), etc.).

And qualitative criteria (Ozone Depletion Potential (ODP), Global Warming Potential (GWP) and maintenance cost (MC)). It is necessary to look for new technique help decision making to select alternative refrigerants, to fulfill the goals of the international protocols (Montreal and Kyoto) and optimum operation, to satisfy the growing worldwide demand, in addition the increase outdoor temperature in some countries.

This study provides a developed methodology for evaluating ACS performance. Moreover, it helps to select a robust decision. The results obtained from AHP process that the best rank of the suitable refrigerant was R404 (0.3763) followed by R22 (0.3657) and so on for the other. Therefore, the proposed methodology can help the decision maker to select the best alternative for both criteria (qualitative and quantitative) in complex selecting process.

1. Introduction

The selection of alternative refrigerants is the most critical decisions taken by the designer and manager in field of refrigerant systems. The decision process is not an easy and generally consists of four stages: defining goals (objective), formulating criteria for the selection of alternative refrigerants, qualifying and ranking the suitable refrigerant, and finally selecting suitable refrigerant. Many different techniques involve the determination of quantitative criteria that can be used to select the best possible alternative [1,2].

A number of studies was conducted to deal with suitable alternative evaluation of refrigerants; Joudi and al-Amir (2014)[3] identified what criteria and parameters were adopted to evaluate and select suitable refrigerants . These quantifiable criteria and parameters were also used to predict that performance of the system. Examples of parameters

---

[*] Corresponding author. Tel.: +964 07812818819
E-mail address: satmutt1961@yahoo.com

involve condenser air temperature, evaporator of exit air temperature, COP, mass flow rate and cooling capacity of ACS. They confirmed that qualitative criteria like, Environment and maintenance have the most important role in the selection process. On other hand, Venkataiah and Venkata,(2014)[4] presented methodology of statistical procedure of analysis for assessment to select an alternative in short list of alternative refrigerants in ACS. But Venkataiah and Venkata's study were supported only quantitative criteria.

1.1. Problem definition

The main problem that faces the designer and manager of ACS is the selection of one alternative among of number of refrigerant which carries the best characteristics to make the system performance optimal. Reaches this goal by using traditional model (using one criterion) is not a perfect and inaccurate process. It is because in designing and decision making processes some realistic criteria such as qualitative criteria like (Environment impact) are not taken into consideration by decision makers and designers [2].

The preference process for specific at refrigerant carries the best characteristics to make the system performance optimal. It will be difficult decision making process.

This study aims to propose a developed model based on MCDM with AHP Process that can aid designers and managers in the selection of the suitable alternative of refrigerants that satisfy the goal to take into consideration both quantitative and qualitative criteria.

1.2. Research Objectives

This study aims to propose a developed model based on MCDM with AHP Process that can:

1- To provides a developed methodology for solving complex problems of multi-criteria decision-making (MCDM).

2-To aid designers and managers in the selection process of the suitable refrigerants fluid that can take into consideration multi-criteria for both quantitative and qualitative criteria.

3- To help designers and managers to select a robust decision for the success and market competition by using Analytical Hierarchy Process AHP.

2.Letreture Review

The analysis of criteria for selection and measuring the performance of alternative refrigerants has been the focus of many scientists and many researchers in the domain of alternative refrigerants selection like research [2,3,5,6].

Shailendra and shishir (2017) [5] explored some of the advantages and disadvantages of R22 and (R410A, R407, R134A and 290) application in ACS. They used compressor performance data and a heat pump simulation model to compare R22 and its suitable refrigerant in air conditioner. The authors concluded that the superior performance of the R410A compressor compensated for the lower thermodynamic efficiency of R410A relative to R22 at low and moderate condensing temperatures. However, the R410A experienced a loss in COP relative to the R22 at high condensing temperatures.

AHP is one of the most commonly used methodologies to selection the best alternative from a set of suitable refrigerant. Bernard, et al, (2014)[7] explain that AHP enables users to create different levels or hierarchies depending on the complexity of the problem. Some of the main advantages of the AHP are that it provides a framework for decomposing and structuring complex, thus decision makers often gain better understanding of the problem and relationships of the individual criteria or attributes. Another key advantage of AHP is that it can synthesize the ranking of suitable refrigerant or options based on different criteria [6].

Elaheh, et al, (2017) [8] proposed and evaluated a decision problem for operation system. They employed AHP to obtain the weights of criteria, as multi criteria decision making to obtain the ranking of suitable refrigerant, when the information was given in linguistic terms. The research was focused to select the best alternative to evaluate optimize of performance a mechanize system in a factory.

This study is based on a comparative performance of alternative refrigerants: R22, R290, R404 and R410C.They were determined theoretically to test the possibility of substituting refrigerant in AC for high temperature applications.

3. Mathematical Modeling

3.1 Refrigeration System Calculations

Many mathematical models were proposed for modeling the systems of refrigeration. These models can be used for simulations and selecting the type of alternative refrigerants by quantitative criteria such as condenser temperature, evaporator temperature, mass flow rate of refrigerant, and cooling capacity CC of the system. These quantitative criteria were rated for designing and evaluating the performance of cooling system. But the qualitative criteria of environment indexes (i.e. GWP and ODP) have not been considered. The qualitative criteria for refrigeration system calculations are as follow[9]:

The Ratio of Pressure RP = P_2/P_1 (1)

The isentropic Compression Work,

WC (KJ/Kg) = m*(H2-H1) (2)

The Cooling Capacity (CC) = m*(H1-H4) (3)

The heat rejected by the condenser

= m*(H2-H3) (4)

The Coefficient Of Performance

$$(COP) = CC/W_C \qquad (5)$$

Where m: the rate of refrigerant mass flow

3.2 AHP calculation:

The AHP uses three steps for analysis principles to help in forming a structure for the problem as below [7]:

Step 1: Create the Problem Hierarchy.

Step 2 : Assignment of Weights by using the Equ.(6) and Table(1) as below [8].

$$P = Pr_{ij} = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{pmatrix} \qquad (6)$$

Where: Pr_{ij} : importance degree of the ith element compared to the jth element.

Table (1) the explanation of intensities (scale) assignment of Weights [8]:

Intensity	Definition of importanc	Explanation
1	Same importance	The two elements(i,j) contribute equally to the goal
3	Moderate importance	Experience moderately favors one element over another
5	Strong importance	Experience strongly favors one element over another
7	Very strong importance	Experience very strongly favors one element over another
9	Extreme importance	Experience Extreme favors one element over another
2,4, 6,8 used for intermediate values		

The matrix is normalized by dividing the values in each column by the sum of the column of Pr normalized (Pr_{Nor}) as follows [7]:

$$Pr_{ij\,Nor} = \frac{Prij}{\sum^{n} Prij}, \quad i, j = 1,2\ldots.,n \qquad (7)$$

the elements weight of the same line (row) for normalization matrix Pr_{Nor} is aggregated as follows :

$$W_{i\,Nor} = \sum_{i=1}^{n\ Nor} Prij \quad , I = 1, 2 \ldots, n \qquad (8)$$

The weights vector W = (w_1, w_2,... w_n) is then found through the following formula:

$$W_i = \frac{Wi_{Nor}}{\sum^{n} Nor\, wi}, \quad i = 1, 2, n \qquad (9)$$

Step 3: The logical consistency. There is procedure used to validate the weights (W_i) in Equ (9) by getting:

I) Original pairwise = (pr*W_i), and П) Eigen Value(λ_{max}) in Equ(10)[7]:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(pr*w)i}{wi} \qquad (10)$$

Finally, the consistency ratio (CR) is computed by:

$$CR = \frac{CI}{RI} \qquad (11)$$

Where RI: is the Random Index. The values of RI, which change with variations in dimensions are shown in Table (2). CI: consistency index is computed by [7].

$$CI = (\lambda_{max} - n)/ (n-1) \qquad (12)$$

When CR ≤0.10, it means that the consistency of the pairwise comparison matrix is acceptable.

Dimension	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

Table (2) the random consistency index [7].

4. Methodology of Developed Model:

Combining between two decisions of teams' designers and managers is the one of important objectives of modern total quality management. The goal of the study is combining of those decisions to reach for robust design by optimal design of products. The methodology model provides three phases; decision of design phase, decision of management phase and decision phase as shown in Fig(1):

Phase1: consists of two branches for selection of alternative refrigerants, criteria and sub-criteria.

Phase2: also consist of two branches for evaluation of criteria of alternative refrigerants as: 1-Objective Criteria: to evaluating of operation indexes by using of software (EES) for sub-criteria depending on Equs (1,2,3 and4). 2-Subjective Criteria: depended on ASHRAE standard 37 used for environment sub-criteria. The result of phase is used to assignment weights of sub-criteria for predate to application in AHP software.

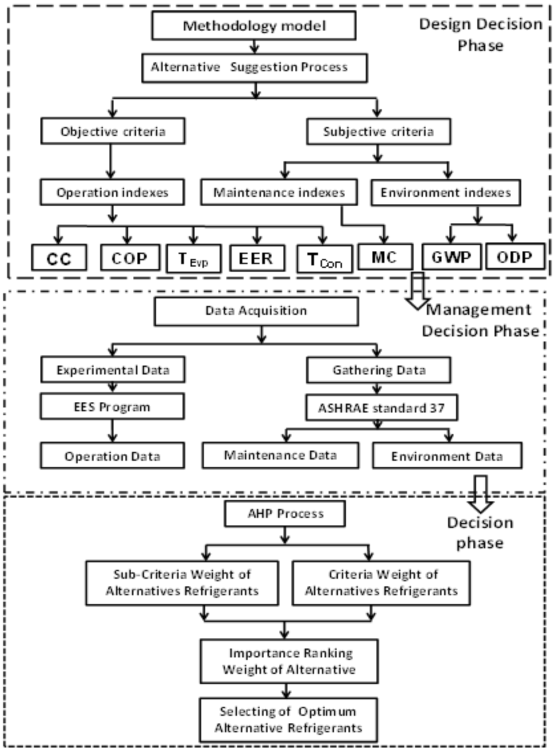
Phase3: AHP is used as a tool for supporting decision in selection among alternative refrigerants regarding multi criteria qualitative and quantitative criteria. Precisely, to find weight of importance for criteria and sub-criteria according to the results is obtained from second phase of Methodology.

5. Case Study:

A case study of small Air Conditioning system was selected to describe the results obtained from using the developed model. The present study investigation is an attempt to assess system performance criteria of air conditioners under high condensing temperatures for R22 and the another refrigerant R290, R404 and R410 in three viewpoints operation environment and maintenance.

5.1.Suitable refrigerant selection

There are many desirable properties (see Table 3) of refrigerants used in refrigeration cycles like; high thermal conductivity, high latent heat of vaporization, good material compatibility, high critical temperature, environmentally friendly (low GWP and ODP), non-toxic, non-flammable, and easy maintenance ; low viscosity, and low cost. However, It is very impossible for any refrigerant to have all those properties in any one AC system. But, it is important in design that the suitable refrigerant have both environmentally friendly and operation efficient. The research suggests for best suitable refrigerants: R22, R290, R404 and R410 which are differ from each other in their properties.



Fig(1):the methodology of developed model

Table (3) properties of selected refrigerants [9]

No.	properties	unit	Refrigerant			
			R22	R404	R410	R290
1	Chemical formula	--	CHCLF2	Ternary mixture	Binary mixture	C3H8
2	$GWP_{100year}$	--	1900	1700	2000	20
3	ODP	--	0.055	10^5	$2*10^5$	0
4	boiling point	^0C	-40.8	-43.6	-51.4	-42
5	Critical pressure	bar	49.89	45.97	49.25	42.5
6	Critical temperature	^0C	96.2	86.79	72.5	96.8
7	density	kg/m^3	43.94	41.94	65.83	20.62
8	Viscosity	kg/m-s	0.00001218	0.00001147	0.00001205	0.0000081
9	Vapor Conductivity	W/m.K	0.011798	0.01427	0.015506	0.08989
10	Molecular weight	kg/kmol	86.48	86.2	27.58	44.1
11	Safety Group	--	A1	A1	A1	A3

5.2 Data Acquisition

A large number of theoretical and experimental studies were found in literature pertaining for various refrigerant and their suitable refrigerant by researchers from various parts of the world. The studies focused on the quantitative performance parameters and relationship between them by using a number of software with ideal cycle condition. The results of these studies will been depended as an input data for the second part of the developed model. This study focuses on vital eight parameters: cooling capacity (CC), coefficient of performance (COP), evaporating temperature TEvp, condensing temperatures Tcon, energy efficiency of rate (EER), Ozone Depletion Potential (ODP), Global Warming Potential (GWP) and maintenance cost (MC) with ideal cycle condition.

1.Subjective data

The many of previous research focused on criteria in which measuring impact of some refrigerants on environment based on ASHRAE standard 37. These data of criteria are gathered depending on the studies [5,6,10,11,12].

1- Safety Group SG: According to ASHRAE standard 34 (see Table(1)), the R22, R404 and R410 are A1, but R290 is classified as A3 class refrigerant, which means that it is a nontoxic and highly flammable refrigerant.

2- GWP: The R290 is very low effect on global heating from other refrigerant. The indirect effect is also expected to be lower because of its excellent thermo–physical properties.

3- ODP: R22 is very high effect on ODP from other refrigerants follows R410,R404 and R290 is Zero.

2.Experimental data

The experimental results are calculated based on the refrigerant enthalpy at inlet and outlet of each component for each selected refrigerants. The eight parameters of refrigeration were calculated by the well-known Equs.(1-5). Finally, all data were gathered from previous researches and then using it to input in AHP process.

In the following sections the listing of these collect results about four suitable refrigerant refrigerants collected or gathering for researches [1,3,4,5,6,9,11].

1- The most affecting on COP are a refrigerant's critical temperature and molar heat capacity, with a lower critical temperature will tend to have a lower COP.

2- The four refrigerants have similar COP at low condensing temperatures T_{con} when T_{con} increase (above 35°C), the COP values decrease for all refrigerants except R410. This means: that the COP of R410 is more sensitive to high T_{con}. With R290 has the highest COP among the suitable refrigerant refrigerants but the COP of R404 seems to be similar to R22, as excepted.

3- The value of COP changes with the evaporation temperature T_{Evp} for compared with R22. For R290 the highest COP (similar to R22) is followed by R410 (-8.69%), and R404 (-11.22%) the lowest when T_{Evp} increases.

4- The evaporating temperature TEvp increases steadily as the Tcon increases for all refrigerants except R410, because the increment in evaporating pressure for R410 is more than the suitable refrigerant refrigerants[2].

5- When TEvp increases the pressure ratio decreases continuously for all the selected refrigerants in comparison with R22. The ranking of percentage decreasing of pressure ratio is R404 (-2.19%), R290 (-6.27%) and there is not much variation in the pressure ratio for R410.

6- The system has high CC at the standard rating conditions (35°C outdoor air temperature), but lose CC when the Tcon increases at 50°C, the CC of R410 drops faster than the other refrigerants because of its low critical temperature (72.5°C). R410 increases about 4.0 % than that of R22 while it decreases for R404 and R290 about 2.0 % and 4.5 % than that of R22, respectively.

7- For the R22, EER decreased by 35 % and for R410 by 42 % at high Tcon. For 290 and 404, EER was approximately 2 % lower and 6.5 % at high Tcon, respectively.

8- The compressor power consumption CP decreases linearly with an increase in TEvp. The ranking percentage increasing of CP input for suitable refrigerant refrigerants is as follows: R290(1.1%), R410 (10%), R404 (13.5%) than that of R22.

9- The compressor power CP consumption increases with increasing T_{con} above 35°C. This is because the CP is affected by two factors, the refrigerant mass flow rate and the compression ratio. The comparison shows that the power consumption of R410 and R404 are higher, about 16% and 4%, respectively, and R290 is lower about 10% , as compared to R22 under same operating conditions.

10- For all the refrigerants, the mass flow rate decreases linearly with increasing evaporation temperature. Therefore the CP vs T_{Evp} comparison shows that the CP percentage similar to the above paragraph.

11- The lower liquid density of R290 reflects the lower requirement of refrigerant mass resulting in lower friction and better heat transfer coefficients in evaporator and condenser. R290 has lower viscosity and higher thermal conductivity which improves the performance of condenser and evaporator.

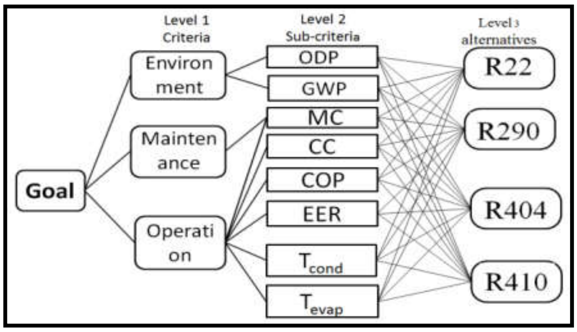
12- For best comparison of effect of the transport properties of heat and the pressure drop (ΔP) characteristics for the selected refrigerants are required. The R290 has better heat transfer among four refrigerants. In addition, it has the highest (ΔP) but R410 has the lowest. These conclusions were expected because the R290 has the lowest vapor density. R410 has best heat transfer than R22 and R404.

13- Cost: The manufacturing cost of the system of R410 is 4.2% lower and the R404 is 1.8% higher than that of R290 and R22. The hydrofluorocarbon (HFC) systems would use the additional cost for a larger condenser. The mixture refrigerant (R404 and R410) has the low volumetric capacity then that it requires a larger volume compressor concluded to adding high cost.

Analysis of these results of data for subjective and objective are conducted, and then used in AHP.

5.3. Applying AHP

Create the Problem Hierarchy: From the first step of the AHP process is defined the decision criteria in form of the hierarchy of goals. This involves identifying the goals, criteria, sub-criteria and suitable refrigerant as illustrated in Fig(2). The model consists of a set of suitable refrigerant. They are refrigerants (R404, R410, R290 and R22) for three main criteria (Environment, Maintenance and Operation) and eight sub-criteria (ODP, GWP, Maintenance Cost MC, CC, COP, EER, T_{con} and T_{Evp}).



Fig(2): Hierarchical decision tree

The evaluation of the criteria and sub-criteria weights, the result of matrix Pr , normalization matrix Pr_{Nor} and weights vector W_i are listed in table (4 A,B).

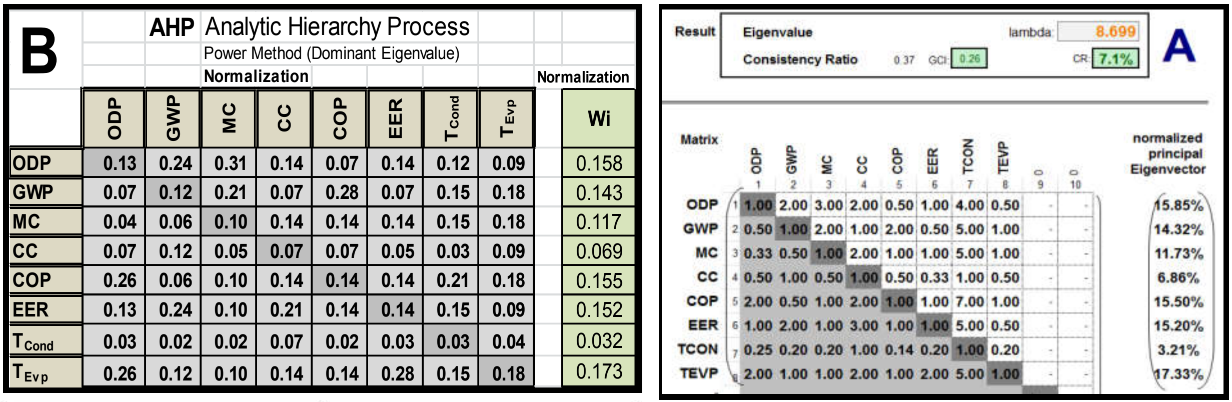
From Table (4) and Fig (3), the weight of T_{Con} is the highest impact on the performance of system and then ODP follows COP and so on.

The logical consistency:

The procedure to validate these weights is by using Equs.(10,11,12,13). This procedure is built-in AHP program, the result represented by two symbols λ_{max} and CR as in the above box in Table(4a). In this study results are as follows: $\lambda_{max} = 8.699$ and $CR = 0.071 < 0.10$. Therefore, no serious inconsistency exists.

Once the decision analyst has determined that the consistency is sufficient, the next step is to calculate the final weights from the matrix.

Table (4) listed the result of Pr , Pr Nor and Wi of sub-criteria



B **AHP** Analytic Hierarchy Process

Power Method (Dominant Eigenvalue)

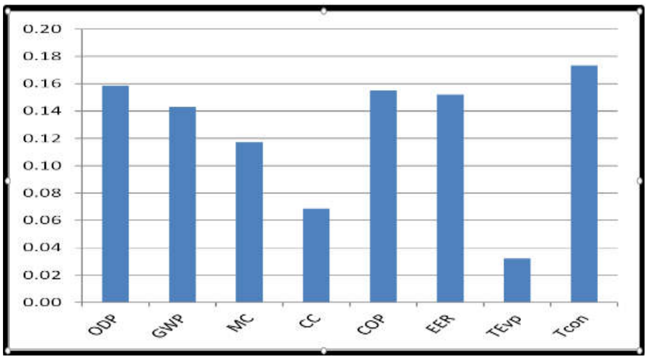
	ODP	GWP	MC	CC	COP	EER	T_{Cond}	T_{Evp}	Wi
	Normalization								Normalization
ODP	0.13	0.24	0.31	0.14	0.07	0.14	0.12	0.09	0.158
GWP	0.07	0.12	0.21	0.07	0.28	0.07	0.15	0.18	0.143
MC	0.04	0.06	0.10	0.14	0.14	0.14	0.15	0.18	0.117
CC	0.07	0.12	0.05	0.07	0.07	0.05	0.03	0.09	0.069
COP	0.26	0.06	0.10	0.14	0.14	0.14	0.21	0.18	0.155
EER	0.13	0.24	0.10	0.21	0.14	0.14	0.15	0.09	0.152
T_{Cond}	0.03	0.02	0.02	0.07	0.02	0.03	0.03	0.04	0.032
T_{Evp}	0.26	0.12	0.10	0.14	0.14	0.28	0.15	0.18	0.173

A

Result Eigenvalue lambda: 8.699

Consistency Ratio 0.37 GCI: 0.26 CR: 7.1%

Matrix	ODP 1	GWP 2	MC 3	CC 4	COP 5	EER 6	TCON 7	TEVP 8	0 9	0 10	normalized principal Eigenvector
ODP 1	1.00	2.00	3.00	2.00	0.50	1.00	4.00	0.50	-	-	15.85%
GWP 2	0.50	1.00	2.00	1.00	2.00	0.50	5.00	1.00	-	-	14.32%
MC 3	0.33	0.50	1.00	2.00	1.00	1.00	5.00	1.00	-	-	11.73%
CC 4	0.50	1.00	0.50	1.00	0.50	0.33	1.00	0.50	-	-	6.86%
COP 5	2.00	0.50	1.00	2.00	1.00	1.00	7.00	1.00	-	-	15.50%
EER 6	1.00	2.00	1.00	3.00	1.00	1.00	5.00	0.50	-	-	15.20%
TCON 7	0.25	0.20	0.20	1.00	0.14	0.20	1.00	0.20	-	-	3.21%
TEVP 8	2.00	1.00	1.00	2.00	1.00	2.00	5.00	1.00	-	-	17.33%

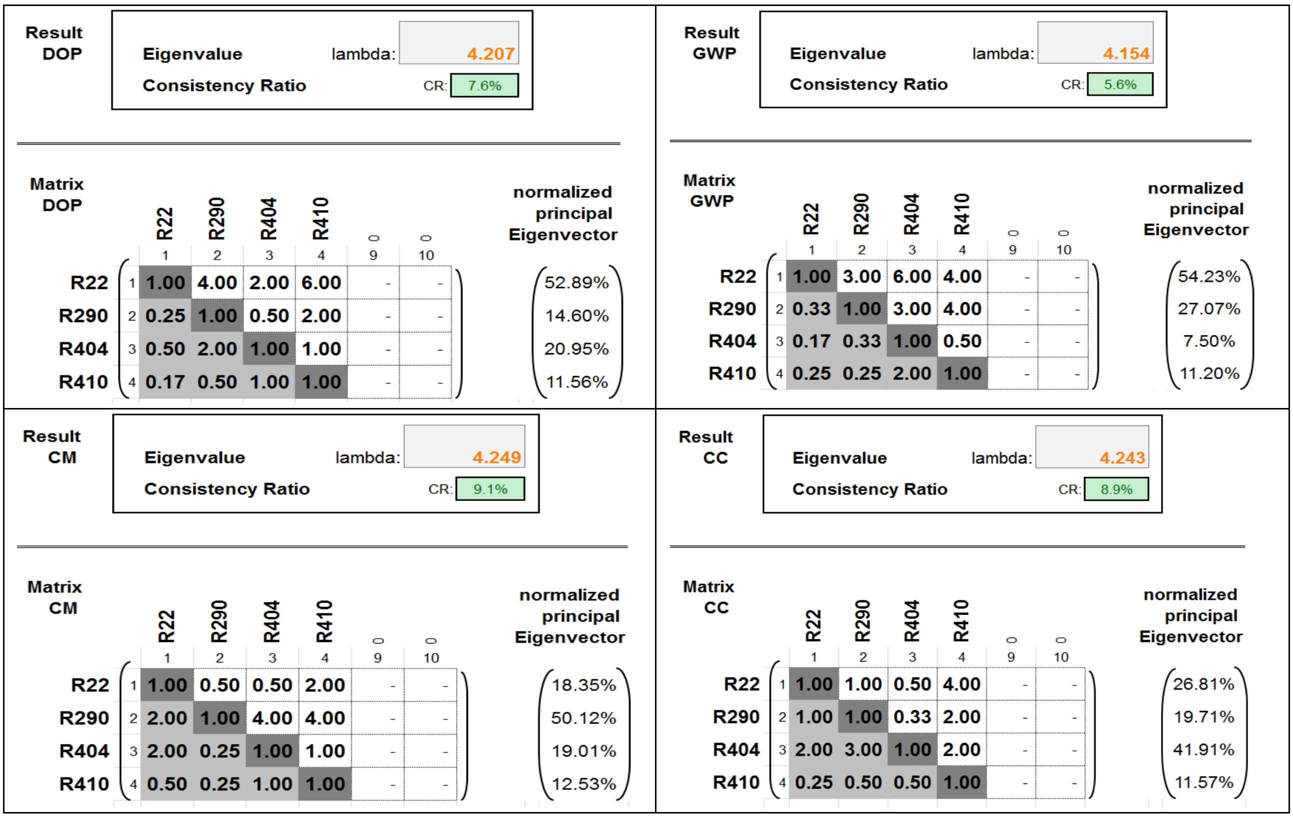


Fig(3). Schematic representation of the hypothetical case study

5.4. Prioritization and Identification of Preferred selected refrigerants :

Table (5) shows the selected refrigerants (R22, R290, R404, and R410) relative to each sub-criterion using importance compared to the sub-criterion with validate of its weights by λ_{max} and CR.

Table (5). comparison of suitable refrigerant of refrigerants relative to each sub-criterion



Result DOP Eigenvalue lambda: 4.207

Consistency Ratio CR: 7.6%

Matrix DOP	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	4.00	2.00	6.00	-	-	52.89%
R290 2	0.25	1.00	0.50	2.00	-	-	14.60%
R404 3	0.50	2.00	1.00	1.00	-	-	20.95%
R410 4	0.17	0.50	1.00	1.00	-	-	11.56%

Result GWP Eigenvalue lambda: 4.154

Consistency Ratio CR: 5.6%

Matrix GWP	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	3.00	6.00	4.00	-	-	54.23%
R290 2	0.33	1.00	3.00	4.00	-	-	27.07%
R404 3	0.17	0.33	1.00	0.50	-	-	7.50%
R410 4	0.25	0.25	2.00	1.00	-	-	11.20%

Result CM Eigenvalue lambda: 4.249

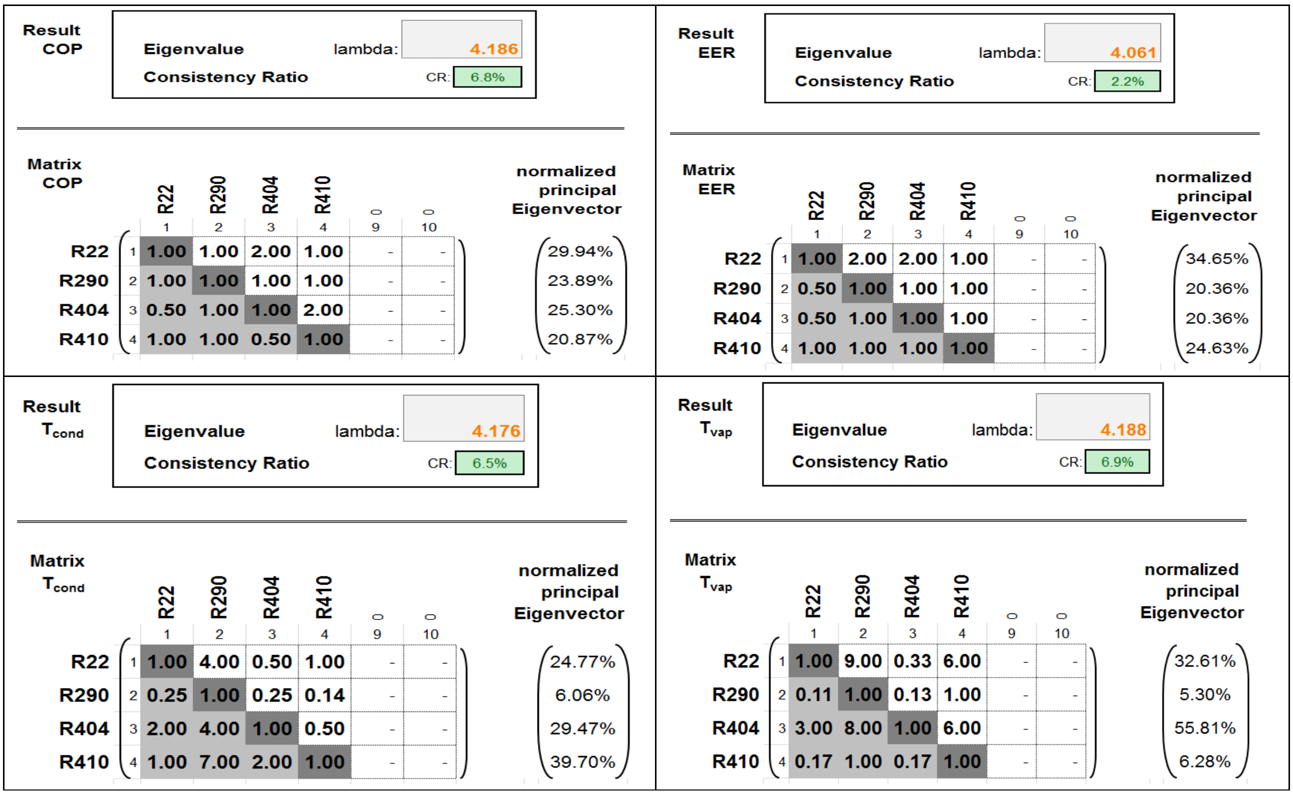
Consistency Ratio CR: 9.1%

Matrix CM	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	0.50	0.50	2.00	-	-	18.35%
R290 2	2.00	1.00	4.00	4.00	-	-	50.12%
R404 3	2.00	0.25	1.00	1.00	-	-	19.01%
R410 4	0.50	0.25	1.00	1.00	-	-	12.53%

Result CC Eigenvalue lambda: 4.243

Consistency Ratio CR: 8.9%

Matrix CC	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	1.00	0.50	4.00	-	-	26.81%
R290 2	1.00	1.00	0.33	2.00	-	-	19.71%
R404 3	2.00	3.00	1.00	2.00	-	-	41.91%
R410 4	0.25	0.50	0.50	1.00	-	-	11.57%



Result COP

Eigenvalue lambda: 4.186

Consistency Ratio CR: 6.8%

Matrix COP

	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	1.00	2.00	1.00	-	-	29.94%
R290 2	1.00	1.00	1.00	1.00	-	-	23.89%
R404 3	0.50	1.00	1.00	2.00	-	-	25.30%
R410 4	1.00	1.00	0.50	1.00	-	-	20.87%

Result EER

Eigenvalue lambda: 4.061

Consistency Ratio CR: 2.2%

Matrix EER

	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	2.00	2.00	1.00	-	-	34.65%
R290 2	0.50	1.00	1.00	1.00	-	-	20.36%
R404 3	0.50	1.00	1.00	1.00	-	-	20.36%
R410 4	1.00	1.00	1.00	1.00	-	-	24.63%

Result T_{cond}

Eigenvalue lambda: 4.176

Consistency Ratio CR: 6.5%

Matrix T_{cond}

	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	4.00	0.50	1.00	-	-	24.77%
R290 2	0.25	1.00	0.25	0.14	-	-	6.06%
R404 3	2.00	4.00	1.00	0.50	-	-	29.47%
R410 4	1.00	7.00	2.00	1.00	-	-	39.70%

Result T_{vap}

Eigenvalue lambda: 4.188

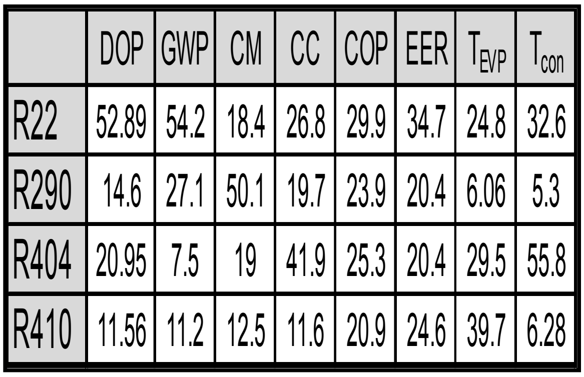
Consistency Ratio CR: 6.9%

Matrix T_{vap}

	R22 1	R290 2	R404 3	R410 4	0 9	0 10	normalized principal Eigenvector
R22 1	1.00	9.00	0.33	6.00	-	-	32.61%
R290 2	0.11	1.00	0.13	1.00	-	-	5.30%
R404 3	3.00	8.00	1.00	6.00	-	-	55.81%
R410 4	0.17	1.00	0.17	1.00	-	-	6.28%

Table (5) summarizes the results of sub-criterion importance weights that affecting on performance of suitable refrigerant refrigerants (R22, R290, R404, and R410), and listed in Table (6).

Table (6) summarizes importance weights of each sub-criterion with the suitable refrigerant



	DOP	GWP	CM	CC	COP	EER	T_{EVP}	T_{con}
R22	52.89	54.2	18.4	26.8	29.9	34.7	24.8	32.6
R290	14.6	27.1	50.1	19.7	23.9	20.4	6.06	5.3
R404	20.95	7.5	19	41.9	25.3	20.4	29.5	55.8
R410	11.56	11.2	12.5	11.6	20.9	24.6	39.7	6.28

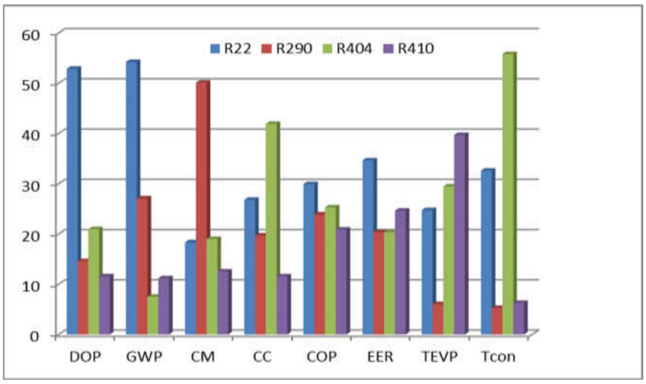
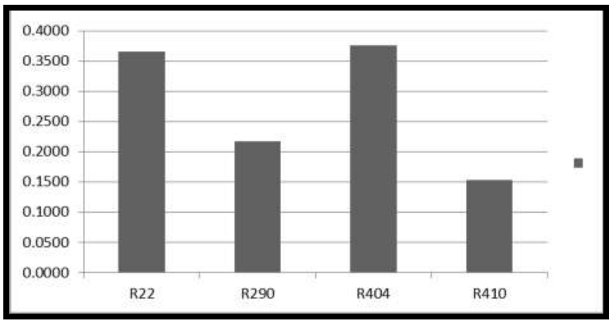


Fig (4): difference of the effect of each sub-criteria on the performance of the system.

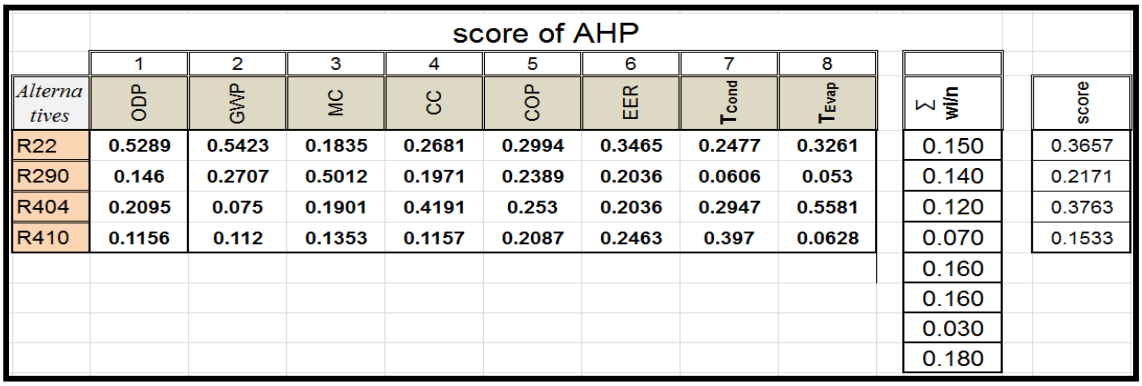
Figure (4) shows the variation of the values for the four suitable refrigerant refrigerants performance measurements versus each one of the eight sub-criteria. The difference in the effect of each sub-criteria on the performance of the system can be observed. These observed results are significant challenges facing managers and designers. So, the process of preference of a specific refrigerant in which carries the best characteristics to make the system performance is optimal, it will be a difficult and complicated process. To solve this problem, there is a procedure based on arranging the selected refrigerants which carries collecting of the best characteristics to make the system performance optimal.



Fig(5) shows the scoring of results

This is obtained from multiplying the weights column W_i of sub-criteria in Table (4-B) with the matrix of importance weights that represented the results effecting of sub-criterion on performance of suitable refrigerant refrigerants in Table (6). Summary of the final results of the AHP for case study is listed in Table (7). These results will be helping the decision maker to make his decisions more robust when selecting one of the suitable refrigerant through a computational process.

Table (7) the final results of the AHP



score of AHP

	1	2	3	4	5	6	7	8		
Alternatives	ODP	GWP	MC	CC	COP	EER	T_{Cond}	T_{Evap}	$\sum$ wi/n	score
R22	0.5289	0.5423	0.1835	0.2681	0.2994	0.3465	0.2477	0.3261	0.150	0.3657
R290	0.146	0.2707	0.5012	0.1971	0.2389	0.2036	0.0606	0.053	0.140	0.2171
R404	0.2095	0.075	0.1901	0.4191	0.253	0.2036	0.2947	0.5581	0.120	0.3763
R410	0.1156	0.112	0.1353	0.1157	0.2087	0.2463	0.397	0.0628	0.070	0.1533
									0.160	
									0.160	
									0.030	
									0.180	

The final results of the scoring column in Table (7) and Fig(5) as a case study are: The values of R404 and R22 of the highest scoring were (0.3763& 0.3657) respectively. Based on the above results, there will be selection for the preferred selected refrigerants (R404 and R22) in the decisions making process for air conditioners, so R404 is the best. The ranking of the suitable refrigerant above has been based on a number of performance indexes which affect the best choice of suitable refrigerant. The performance indexes (sub-criteria) of the most influential index in this choice are the operation criteria (T_{vap} , EER, COP) and Environment criteria (DOP, GWP) respectively.

The analysis of results to determine the suitable refrigerants relative to criteria employed is suitable for decisions making process, which should be applied in air conditioners for high temperature applications to make collection between the qualitative criteria (operation criteria) and qualitative criteria (Environment and maintenance criteria). This study can help the decision maker (designer and management) to reach optimal of performance of conditioner systems and robust decision making.

6. Conclusion and Recommendations

The using AHP in materials selection in this study provides a methodology for assignment of more suitable choice to optimal performance criteria (operation and environment) consistency. As with all complex systems problems, selecting the more suitable process was AHP process for designing conditioner systems. Figure (4) shows the variation of difference in the effect of each sub-criteria on the performance of the system.

The study proposed a developed model for helping managers and designers to facing this effect. The methodology of the model is based on AHP process to prefer a specific refrigerant which carries the best effecting to make the system performance optimal. From table (7), the results obtained from the developed model are that the best rank of the selected refrigerants was R404 (0.3763) followed by R22 (0.3657) and so on for the other suitable refrigerant. Therefore, the AHP can be used to select the best selected refrigerants for both criteria (qualitative and quantitative), when facing a complex selecting process such as this.

It is recommended that, manager and designer of the air condition AC system should adopt the AHP process of selecting refrigerant with high efficiency performance and lowest impact on environment in AC system, this will improve its operational performance through increasing the level of application of the international standards for performance and environment together. Therefore, further research can be used another tool with another suitable refrigerant.

7.References:

[1] H. K. Dawood, Sattar. A. Mutlag, K. A. Abed and O. I. Abed, “Priority-Based Decision Support System (PBDSS) by Genetic Algorithm as a Tool for Network Problem,” 2018 11th International Conference on Developments in eSystems Engineering (DeSE), Cambridge, United Kingdom, 2018, pp. 306-311.

[2] Suxin Q., Dennis N., Adam R., Yi W., Yunlong G., Yunho H., Reinhard R. and Ichiro T. "A Quantitative Comparison of Refrigerants and System Performance" Elsevier, International Journal of Refrigeration No.6 PP.(78 – 99), 2015.

[3] Oudi, Kh, A ., Al-Amir Q. R. "Experimental Assessment of residential split type air-conditioning systems using alternative refrigerants to R-22 at high ambient temperatures" Elsevier, Energy Conversion and Management No.86, PP. (496–506), 2014.

[4] Venkataiah S. and Venkata R. G. " Analysis of Alternative Refrigerants to R22 for Air-Conditioning Applications at Various Evaporating Temperatures" Journal of Engineering Research and Applications, No.3 Vol. 4 PP.(39-46), 2014.

[5] Shailendra, K., and Shishir, B. "Performance of R407C as an Alternate to R22: A Review" International Conference on Recent Advancement in Air conditioning and Refrigeration RAAR Elsevier, Science Direct, Energy Procedia No. 109, PP. (4 – 10) , 2017.

[6] Choudhari, C. S., and Sapali, S. N. "Performance Investigation of Natural Refrigerant R290 as a Substitute to R22 in Refrigeration Systems" International Conference on Recent Advancement in Air Conditioning and Refrigeration, RAAR, Elsevier, Science Direct, Energy Procedia No.109 PP. (346 – 352) , 2017 .

[7] Ferhat Karaca "An AHP-based indoor Air Pollution Risk Index Method for cultural heritage collections" Elsevier, Journal of Cultural Heritage, No.60 PP.(1–11), 2014.

[8] Elaheh, J. Johansson, P., & Mahapatra, K."Application of analytical hierarchy process for selecting an alternative to evaluate optimize of performance a mechanize system" Taylor & Francis Group, Engineering and Design Management, Vol.13 No.4, P.P.(308-324), 2017.

[9] Khalid A., Qusay R."Performance Evaluation of Small Scale Air-Conditioning System Using R22 and Alternative Refrigerants" Journal of Engineering, No.1 Vol.20 PP. (62-150), 2014.

[10] Mohanraj M., Jayaraj S. and Muraleedharan C. "Environment friendly suitable refrigerant to halogenated refrigerants-A review" Elsevier, international journal of greenhouse gas control . No.l3 PP.(108 – 119), 2009.

[11] Benhadid S.,and Benzaoui A. "Refrigerants and their environmental impact Substitution of hydro chlorofluorocarbon HCFC and HFC hydro fluorocarbon. Search for an adequate refrigerant" Elsevier, Energy Procedia No.18, pp.(807 – 816), 2012.

[12] ASHRAE Handbook of Fundamental, American society for Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, Chapter 6, 2010.