Life-Cycle Cost Analysis for Three Different Types of A/C Systems Applied on an Apartment Located in a Multi-Floors Residential Tower in Mosul City

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ABSTRACT

This research studies the life cycle cost analysis using detailed cooling and electrical load profiles to calculate initial and running costs to evaluate the economic feasibilities of three different types of air conditioning systems as residential air conditioning system (RACs), commercial air conditioning system (CACs) and multi power air conditioning system (MPACs). The present-worth cost method for life-cycle cost period for ten (10) years analysis is applied to a sample building located in Mosul city / Iraq so as to select the best air conditioning system. The cooling load temperature differential with cooling load factor (CLTD/CLF) was used with hourly analysis program (HAP v4.6) for the estimation cooling load in each room of apartment.

The results showed that the RAC system is lower than CAC and MPAC systems in initial cost approximately 53% and 67% respectively and the running cost for CAC system is lower than RAC and MPAC systems approximately 12% and 7% respectively for one month. The the total cost for two systems RAC and CAC are equal after 20 months of the beginning run and after even break point (BEP) the total cost for CAC system began to decline which indicates there is save in electric consumption and present worth cost over a period of (10) ten years after operation interval. The CAC system uses duct always to distribute air into each condition zone, therefor this system gives less noise of air distribution with best interior aesthetic appearance so that it fits with the interior decoration for each rooms of apartment. The outdoor unit of CAC system doesn't appearance because the system working for long distances and can put outdoor units on the roof of the building.

Keywords: Life Cycle Cost Analysis, Air Conditioning System Design, Initial Cost, Running Cost, Total Cost

تحليل كلفة العمر الافتراضي لثلاث منظومات مختلفة لتبريد وتكييف الهواء لشقة متواجدة في برج سكني متعدد الطوابق في مدينة الموصل

الخلاصة:

يتضمن البحث الحالي تحليل كلفة العمر الافتراضي لثلاث منظومات مختلفة لتبريد وتكييف الهواء وكانت على النحو التالي منظومة تبريد وتكييف منزلية ومنظومة تبريد وتكييف تجارية ومنظومة تبريد وتكييف متعددة الاحمال حيث تم دراسة الكلفة الاولية والكلفة التشغيلية للمنظومات المختلفة بالاعتماد على مخطط

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الاحمال الحرارية والاحمال الكهربائية لنموذج شقة سكنية تقع في برج متعدد الطوابق في مدينة الموصل / العراق ، تم أعتماد طريقة فرق درجات حرارة مع عامل تصحيح حمل التبريد (CLTD/CLF) وبرنامج تحليل الساعات (HAP) أصدار (4.6) من شركة كاريير لحساب احمال التبريد الخاصة بالشقة السكنية. تم ملاحظة أن منظومة التبريد والتكييف المنزلية (RACs) تكون كلفتها الاولية اقل بمقدار 53% عن منظومة التبريد والتكييف التجارية (CACs) و67% عن منظومة التبريد والتكييف متعددة الاحمال (MPACs) وأن الكلفة التشغيلية لمدة شهر واحد فقط لمنظومة التبريد والتكييف التجارية هي أقل من منظومة التبريد والتكييف المنزلية ومنظومة التبريد والتكييف متعددة الاحمال بمقدار 7% و 12% على التوالي، كذلك تم استنتاج أن منظومة التبريد والتكييف التجارية هي أفضل من ناحية الكلفة الكلية (المتمثلة بالكلفة الاولية والتشغيلية) لمدة تشغيلية مقدارها (10) عشر سنوات وأنه بعد مرور (20) شهر من التشغيل الاولي للمنظومات الثلاث سيحدث تطابق في قيم الكلف الكلية لمنظومتي التبريد والتكييف التجارية والمنزلية وبعد تجاوز نقطة التطابق (EBP) سيتم عمل منظومة التبريد والتكييف التجارية مع ربح من ناحية الكلفة التشغيلية على مدار السنوات المتعاقبة وهذا يمثل الربح في اختيار هذا النوع من المنظومات الثلاث، فضلا عن ان منظومة التبريد والتكييف التجارية تستخدم مجرى هوائي دائماً لتمرير الهواء من الوحدة الداخلية وصولاً الى الحيز المراد تكييفه وبالتالي سيتم التحكم من خلال تصميم المجرى الهوائي بمقدار الضوضاء التي يصدرها الهواء الخارج من موزع الهواء لكل حيز مع وجود تناسق كبير بين اشكال والوان موزعات الهواء التي ستكون ملائمة مع التصميم الداخلي لكل حيز. إن منظومة التبريد والتكييف التجارية (CACs) تعمل لمسافات طويلة وبذلك سيكون من السهل جداً وضع الوحدة الخارجية على سطح البرج السكني وبالتالي المحافظة على المظهر الخارجي للبرج السكني .

Nomenclature:

LCC: Life Cycle Cost
ID: Iraqi Dinar
A/C: Air Conditioning
1Ø: Single Phase
3Ø: Three Phase
RACs: Residential Air Conditioning System
CACs: Commercial Air Conditioning System
MPACs: Multi Power Air Conditioning System
AM: Ante Meridiem
PM: Post Meridiem
EBP: Even Break Point
r: Discount Rate
IC: Initial Cost
CLF: Cooling Load Factor
OC: Operation Cost
COPR: Coefficient of Performance in Refrigeration
CLTD: Cooling Load Temperature Difference
VAV: Variable Air Volume
CAV: Constant Air Volume
TR: Ton Refrigerant

INTRODUCTION:

In today's fast-paced economy and unstable fuel market energy conservation is becoming an important issue. Electricity generation authorities focus attention on programs to reduce the demand and/or achieve optimum generation cost. The energy economy can be sufficiently improved by employing techniques to either time the energy demand and/or effectively utilize the available resources. Air conditioning (A/C) systems account for between 16 to 50 % of electricity consumption in many regions around the world [1], therefore improving (A/C) system performance will not only reduce the demand into electric consumption but also can significantly reduce the future capital cost in building of the power plants. Selecting the most suitable and economic air-conditioning system among the available many alternatives is one of the important problems that engineers usually face and it is no secret that the prices of

electrical energy that used to run the air conditioning system is increasing worldwide and the main reason is due to rising prices of fossil energy which is the main source for the production of electric power in the world, and because the electric power generated in Iraq is not enough to meet the country's need for rationalization in the consumption of electricity has been the adoption of this search. An air-conditioning system that saves operating costs usually requires a higher initial investment. In this case, engineers should decide whether it is worth paying the extra first cost for a system that has lower operating cost [2].

A review of literature sources were listed here, Xie and Sheng [4] show that the screw compressor chilled water system is the first choice as running cost to compare with multi-units split using in the residential high tower buildings in Beijing city. Aktacir and Yilmaz [5] show that although initial cost of the variable air volume system (VAV) is higher than constant air volume system (CAV), the present-worth cost of the (VAV) system is lower than that of the CAV system at the end of the lifetime due to lower fan-operating costs that applied to a sample building located in Adana, Turkey. Chainarong C. and Peachrakha D. [6] show coefficient of performance in refrigeration (COPR) is improved by around 6 % to 48%, and electrical consumption is approximately reduced by 4% to 15% from an experimental evaluation of energy saving in a split-type air conditioner with evaporative cooling systems.

In literature through the vision of modern research we can note that these researches did not focus on two types; multi power air conditioning system (MPACs) and commercial air conditioning system (CACs) in addition to not take care of indoor unit and outdoor unit aesthetic appearance of the zone condition and building respectively. The purpose of this work to be compare initial and operating costs together between different three types of air conditioning systems as residential air conditioning system (RACs), commercial air conditioning system (CACs) and multi power air conditioning system (MPACs) with taking into consideration the care of the internal and external appearance of the room and building respectively .The residential apartment as a model located in the third floor consisting of three rooms in the Mosul city / Iraq and the operating time interval of the air-conditioning system between 2:00 post meridiem (PM) to 8:00 ante meridiem (AM) hours. Life-cycle cost for (10) ten years [3] are used to analysis was performed using detailed load estimation.

Description of the sample apartment:

The sample of building is consist of sixth floors located in Mosul city, Iraq (36.3 latitude, 43.2 longitude and 222.5 m altitude), the model apartment that will make simulate located within third floors .The cooling period for Mosul which has a hot and dry climate during summer, covers 153 days approximate between May and September .The gross area of the model apartment is 112 m^2 and the outside surfaces of the walls are light colored, Fig.(1) shows the architectural plan of the model apartment [7]. Two rooms of the apartment face to the west orientation and one room face south orientation. It was assumed that the sample building can be used as a residential building. The indoor-air conditions desired are 25 °C dry bulb temperature and 50% relative humidity.

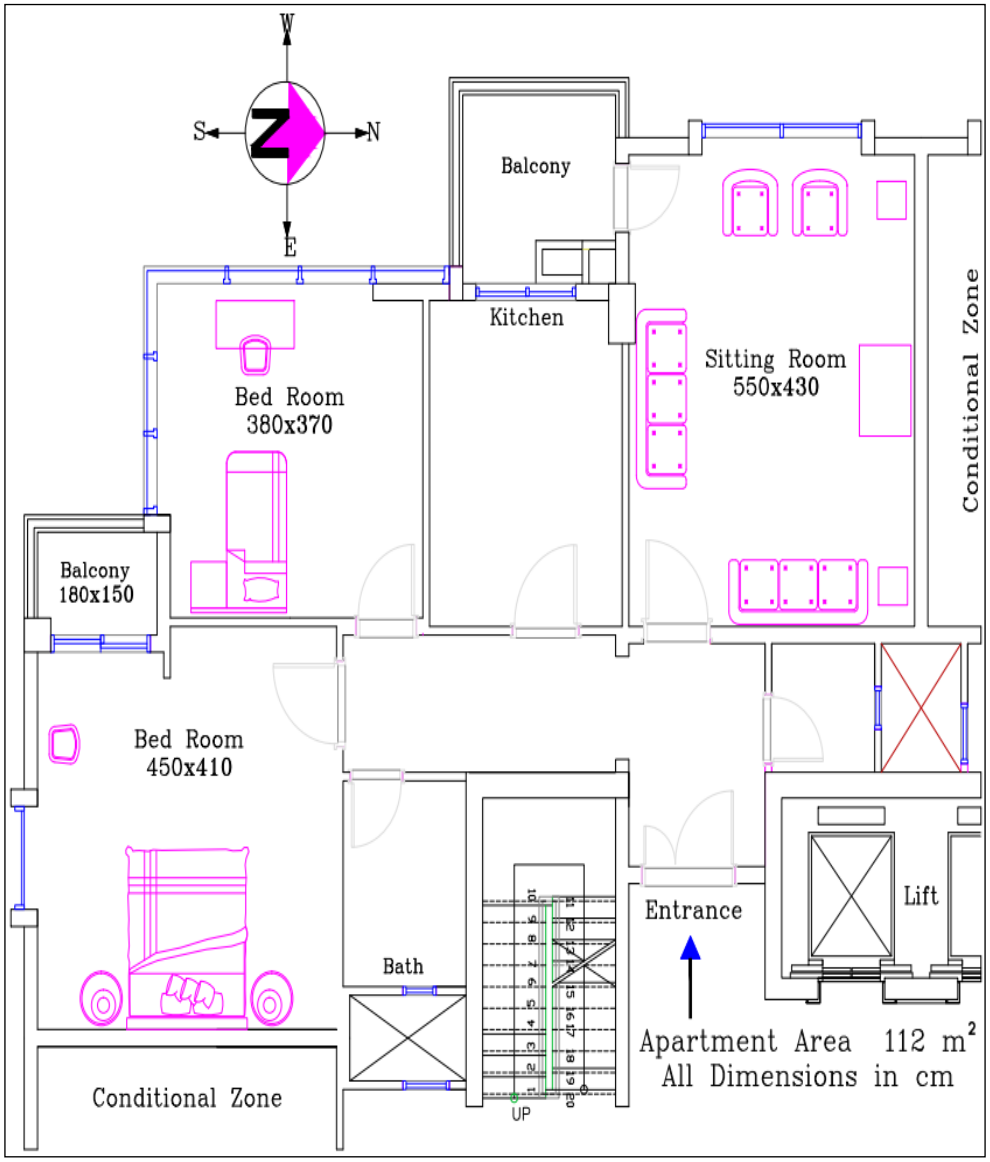


Figure.(1): Architectural Plan of Apartment in the Residential Tower

Description of Cooling Load Estimation:

In this study, cooling load temperature differential with cooling load factor (CLTD/CLF) was used with hourly analysis program (HAP v4.6) for the estimation cooling load in each room of apartment with presented by 10% as modification safety factor for several typical building envelopes which will result in heat storage in the building envelope and furniture release of the stored heat will lead to additional cooling load in subsequent hours [8], Fig.(2) shows the distribution of cooling load estimation with safety factor within each zone of apartment .

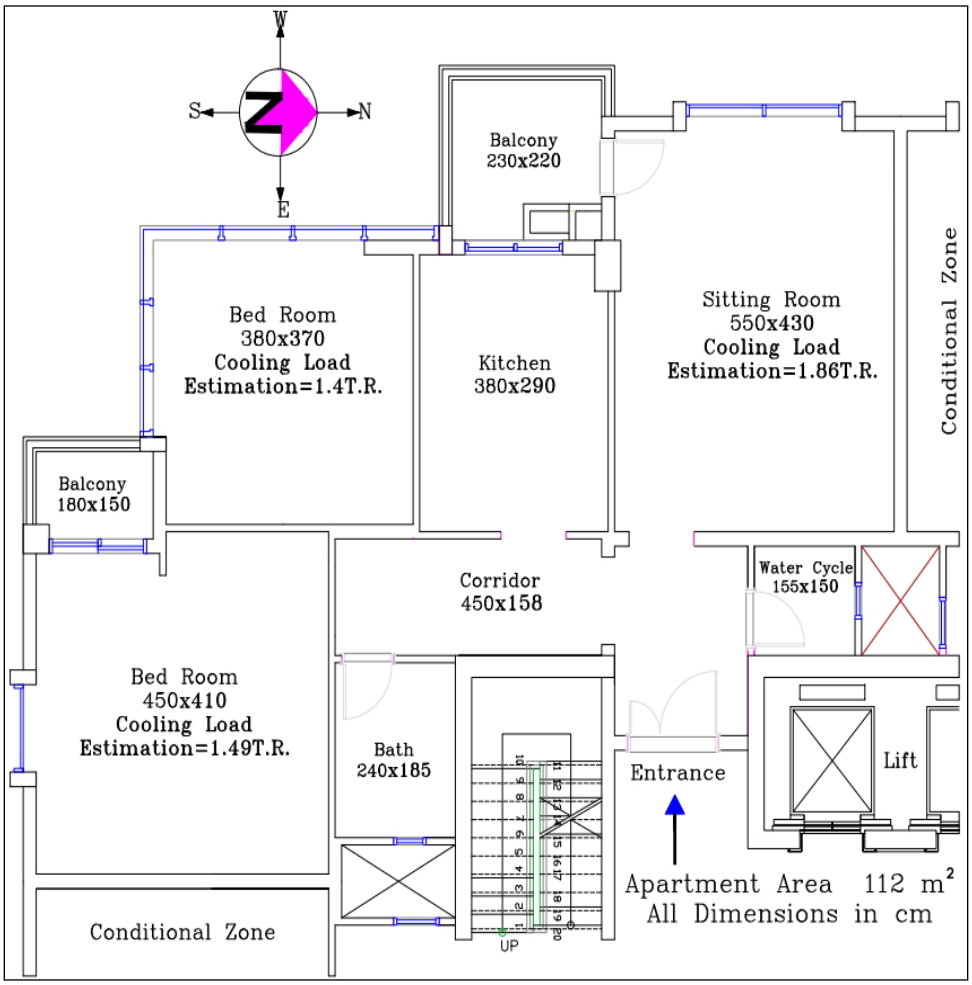


Figure.(2): Distribution of Cooling Load Estimation within each Rooms

Description of the air conditioning system:

The second step after finalization cooling load estimation for the apartment is to choose the appropriate A/C system, in this study three different types of A/C systems will be taking as shown below:

1. Residential Air Conditioning System (RACs)
2. Commercial Air Conditioning System (CACs)
3. Multi Power Air Conditioning System (MPACs)

So as to choose the appropriate A/C system that consumes lower electric during interval running of 10 years and the net operating time 18 hours per one day for every A/C system.

1. Residential Air Conditioning System (RACs):

In this type of A/C systems will use wall mounted type as shown in Fig. (3) and the table (1) illustrates the advantages and disadvantages of this system [9].

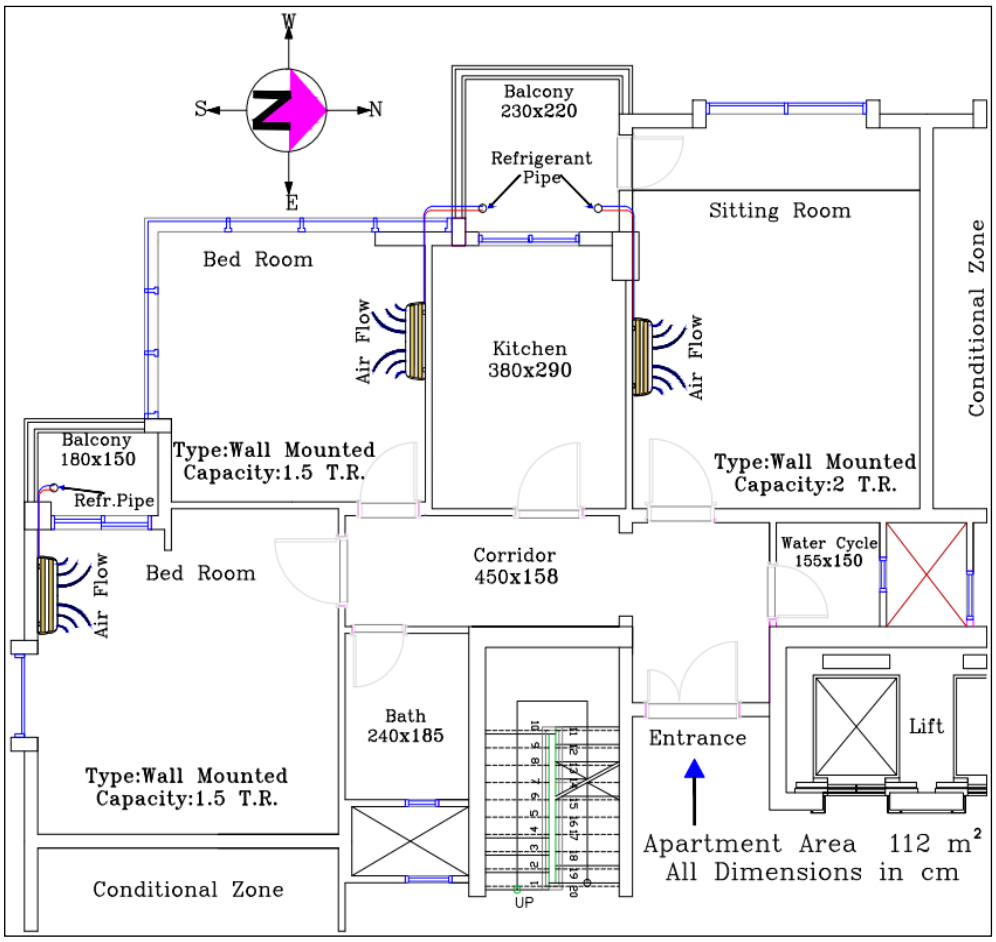


Figure.(3): Wall Mounted A/C System Distribution Details

Table (1): Advantage and Disadvantage of A/C System (RACs)

Description	Appraisal
Type	Residential Air Conditioning / Unitary System
Exterior Aesthetic	Not Acceptable
Interior Aesthetic	Acceptable
Initial & Running Cost	Relative Lower & Relative Higher
Refrigerant Pipe Limit	Limited by 5Meter and Max. 8Meter
Indoor Shape	
Outdoor Shape	

2. Commercial Air Conditioning System (CACs):

In this type of A/C systems will use ceiling concealed duct as shown in Fig.(4) ,usually supply cold or hot air can be conveyed by thermal air duct and distribution by ceiling air diffuser. The advantages and disadvantages shown by table (2) [10].

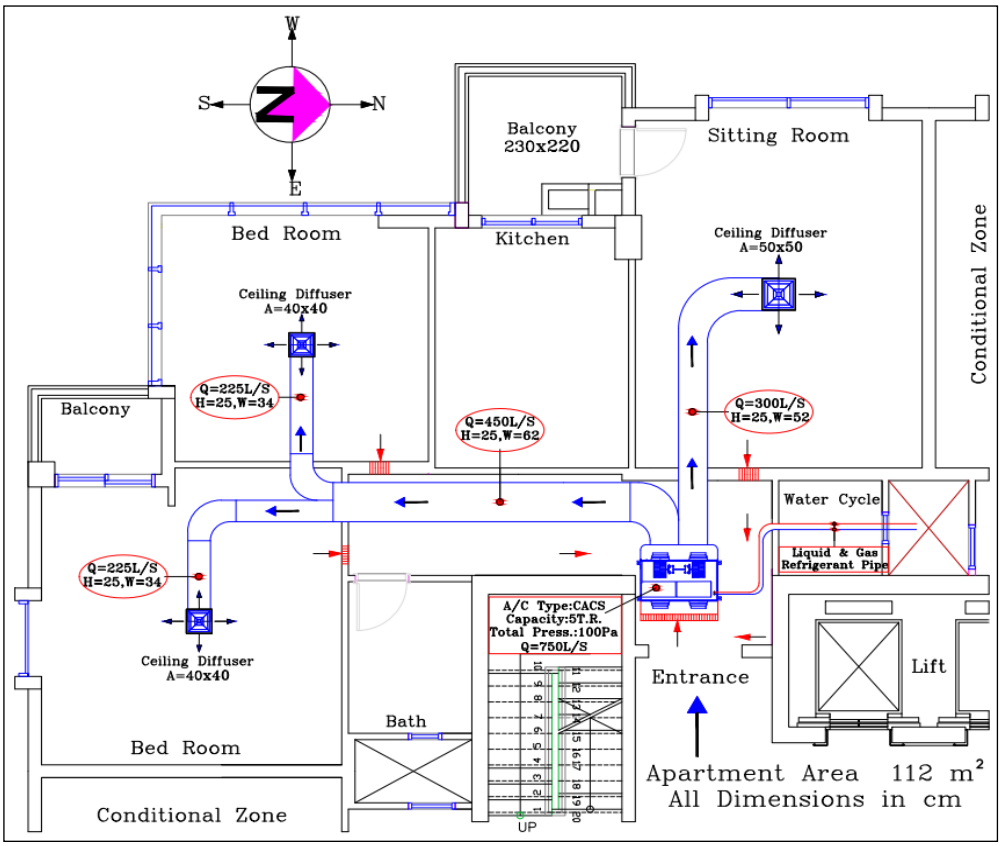


Figure (4): Ceiling Concealed Duct A/C System with Air Duct Design

Table (2): Advantage and Disadvantage of A/C System (CACs)

Description	Appraisal
Type	C.A.C. / Ceiling Concealed Duct
Exterior Aesthetic	Acceptable / Installation on the Building 's Roof
Interior Aesthetic	Excellent
Initial & Running Cost	Relative Higher & Relative Lower
Refrigerant Pipe Limit	50 Meter Between Indoor & Outdoor Unit
Indoor Shape	
Outdoor Shape	

3. Multi Power Air Conditioning System (MPACs):

In this type of air conditioning systems, the multi power air conditioning system with constant speed compressor as shown in Fig.(5) will take in this study , All ways supply cold or hot air can be satisfy by refrigerant R22 directly to each indoor unit by using supply and return refrigerant pipe so as to convey thermal energy from each zone in summer session . The advantages and disadvantages of this system can be illustrated by table (3) [11].

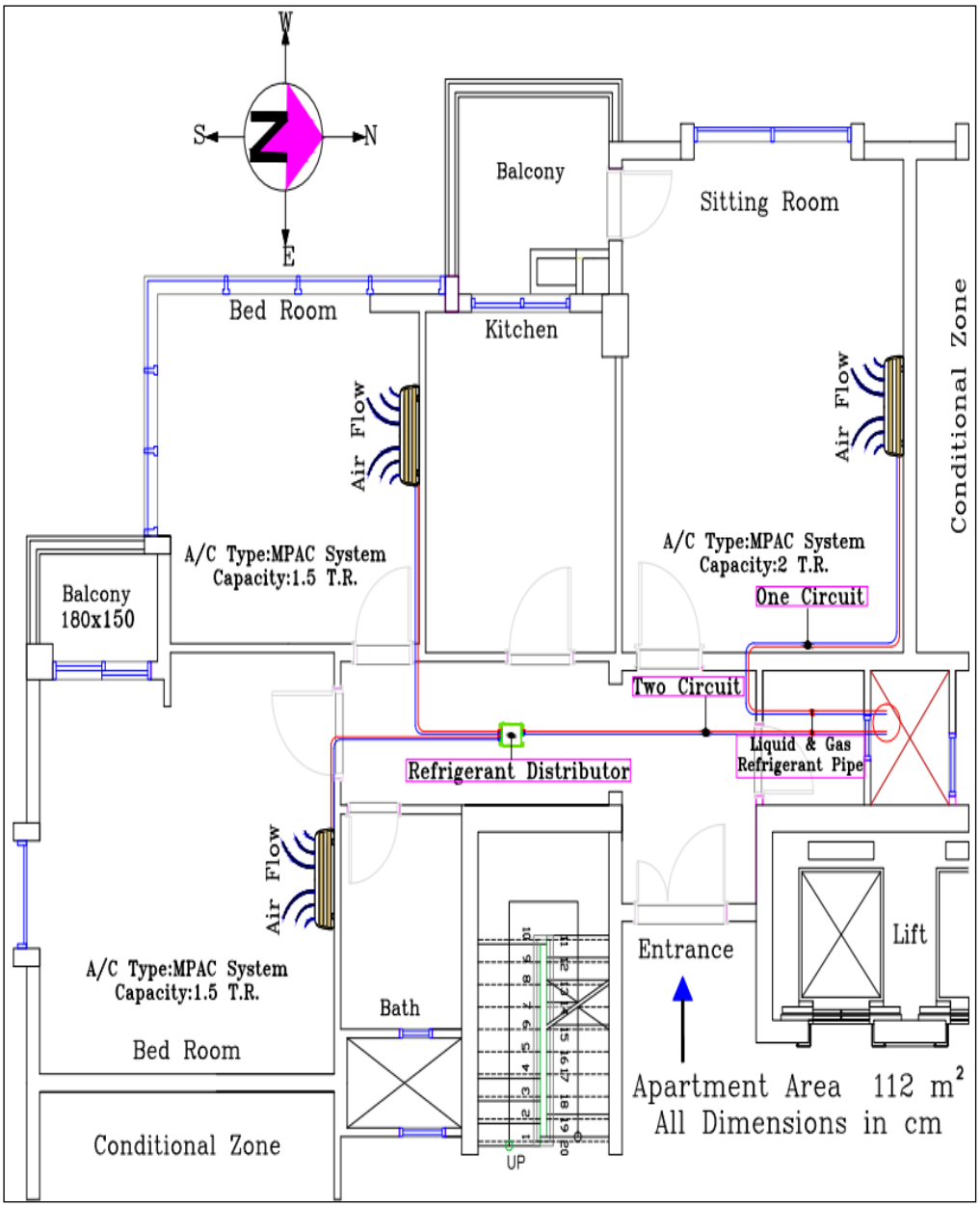
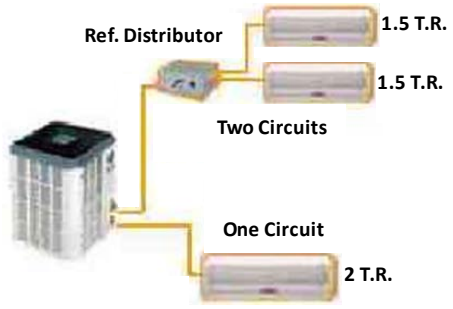


Figure (5):Multi Power A/C System with Refrigerant Pipe Details

Table (3): Advantage and Disadvantage of A/C System (MPACs)

Description	Appraisal
Type	Mini Central Air Conditioning / Multi Power
Exterior Aesthetic	Acceptable / Installation on the Building 's Roof
Interior Aesthetic	Excellent
Initial & Running Cost	Relative Higher & Relative Lower
Refrigerant Pipe Limit	30 Meter for one circuit 50 Meter for two circuit

Indoor & Outdoor Unit Shape	

Costs Analysis for Three Different Types of Air-Conditioning Systems:

For a fair comparison of three different types air-conditioning systems, all the costs (Initial and Operating costs) that will be incurred over the lifetime of the systems should be taken into account and classify into :

1. Initial cost

Initial costs of the A/C system include purchasing and installation cost, tables (4), (5) and (6) shows the estimated initial costs for different A/C systems.

Table (4): Initial Cost Details for Residential Air Conditioning System

Description	No.	Initial Cost ($\times 10^3$ ID)	
		Purchasing	Installation
Wall Mounted Split Unit Capacity 2T.R.	1	812	60
Wall Mounted Split Unit Capacity 1.5T.R.	2	1,100	120
Total Cost of Purchasing & Installation		$2{,}092 \times 10^3$ ID	

Table (5): Initial Cost Details for Commercial Air Conditioning System

Description	No.	Initial Cost (× 10^3 ID)	
		Purchasing	Installation
Ceiling Concealed Duct Split Unit Capacity 5T.R.	1	2,100	130
Duct Work	---	1,400	500
Air Diffuser Work	---	170	90
Total Cost of Purchasing & Installation		4,390 × 10^3 ID	

Table (6): Initial Cost Details for Multi-Power Air Conditioning System

Description	No.	Initial Cost (× 10^3 ID)	
		Purchasing	Installation
MPACS Mini Central Capacity 5T.R.	1	5,200	200
Refrigerant Pipe Work	---	600	300
Total Cost of Purchasing & Installation		6,300 × 10^3 ID	

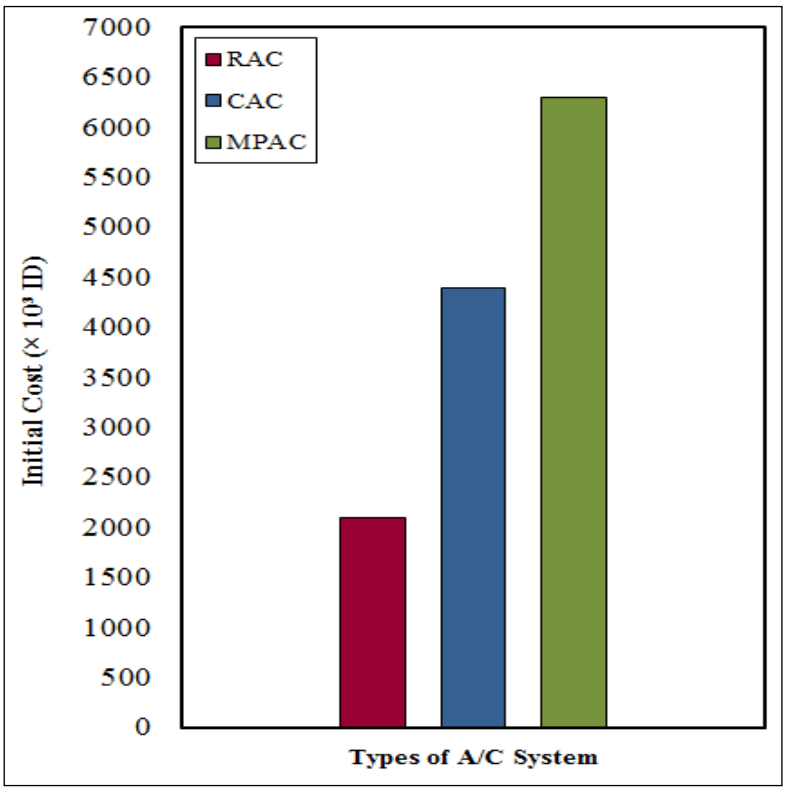


Figure (6): Initial cost for Different A/C

2. Running Cost

Running cost includes the electricity and maintenance costs. Electrical operating cost represents the cost for indoor and outdoor unit for A/C system. Maintenance cost depends on many parameters such as local labor rates, experience, the age of the system, length of time of operation therefore it is difficult to quantify. Complexity of the air-conditioning system and the relative ease of access to plant play an important role on the maintenance cost [12]. A proper estimation of the maintenance cost requires a detailed analysis, Maintenance cost for the RAC, CAC, and MPAC systems can be considered approximately to be the same in the calculations, therefore, maintenance costs were neglected.

Electric power consumption will be estimated to run indoor and outdoor units for different types of A/C system according to electrical unit price which is the amount of electrical energy used in electrical appliances measured in kilowatts unity Hours that adopted at ministry of electricity in Iraqi, while electricity tariff is the sale price of the unit electrical to calculate the cost pre month [13].

The operating time of the A/C system between 2:00 post meridiem (PM) into 8:00 ante meridiem (AM) hours and in other words the net operating time 18 hours per one day, now the ministry of electricity has united all the electricity tariff prices for residential, commercial and industrial application. The equation (1) illustrate the amount of running cost for one month only, the tables (7) and (8) shows the amount of running cost monthly and yearly for three types of A/C systems.

Running Cost per Month (ID) =Amount of Energy (Kw) × Operating Time (Hours) × Electricity Tariff × 30 (Day) ..... (1)

Table (7): Running Cost per Month Details for Types of A/C Systems

A/C System	Amount of Energy (kW)	Operating Time (Hours)	Electricity Tariff (ID/kW.Hr)	Running Cost ($\times 10^3$ ID)
RAC	6.4 (1Ø)	18	50	173
CAC	5.7 (3Ø)	18	50	154
MPAC	6.1(3Ø)	18	50	165

Table (8): Running Cost per one year Details for Types of A/C Systems

A/C System	Amount of Energy (kW)	Operating Time (Hours)	Electricity Tariff (ID/kW.Hr)	Running Cost ($\times 10^3$ ID)
RAC	6.4 (1Ø)	18	50	2076
CAC	5.7 (3Ø)	18	50	1848
MPAC	6.1(3Ø)	18	50	1980

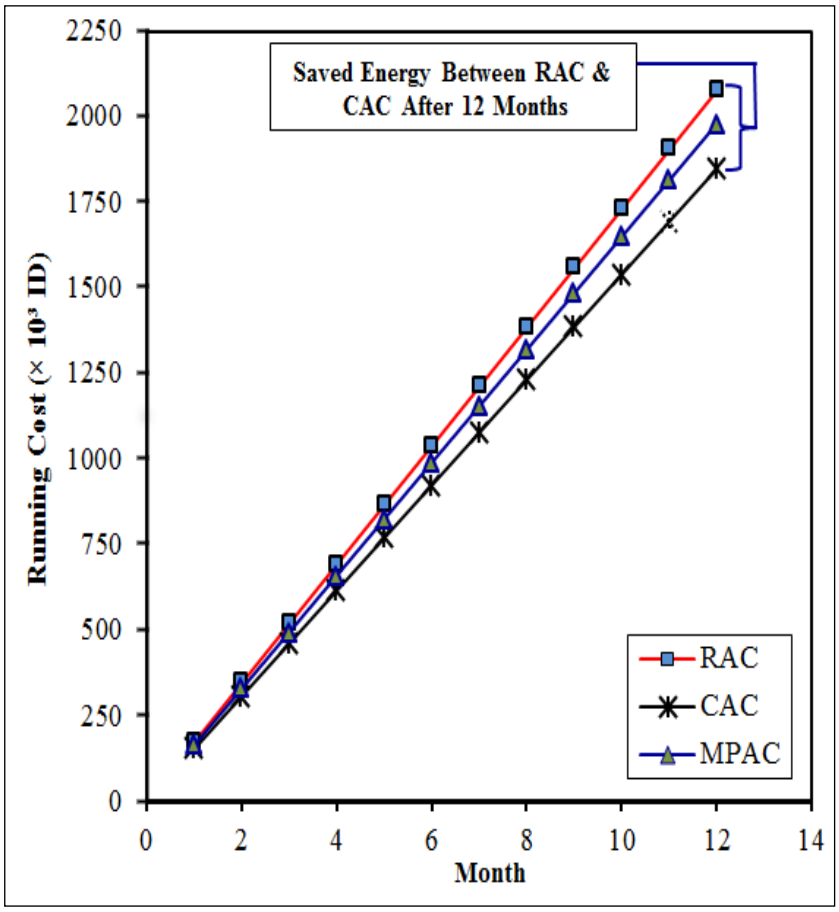


Figure (7):Running Cost for One Year

Life - Cycle Cost Analyses of A/C systems:

A life cycle cost analysis was carried out to analyses of overall initial and operating costs for different A/C systems were developed in this study. The A/C system lives as 10 years [3], therefore in the analysis the present-worth cost technique was used [12] for evaluating the A/C system and used to examine total costs of the three alternative A/C systems, eq. (2) below illustrate the life cycle cost equation [14].

$$LCC = IC + \sum_{n=1}^{n=10} \frac{OC}{(1+r)^n} \qquad \text{..... (2)}$$

Now, in Iraq will be the negligence the discount rate on electric power consumption based on the instructions of the Ministry of Electricity, then the eq.(2) become:

$$LCC = IC + \sum_{n=1}^{n=10} OC \qquad \text{..... (3)}$$

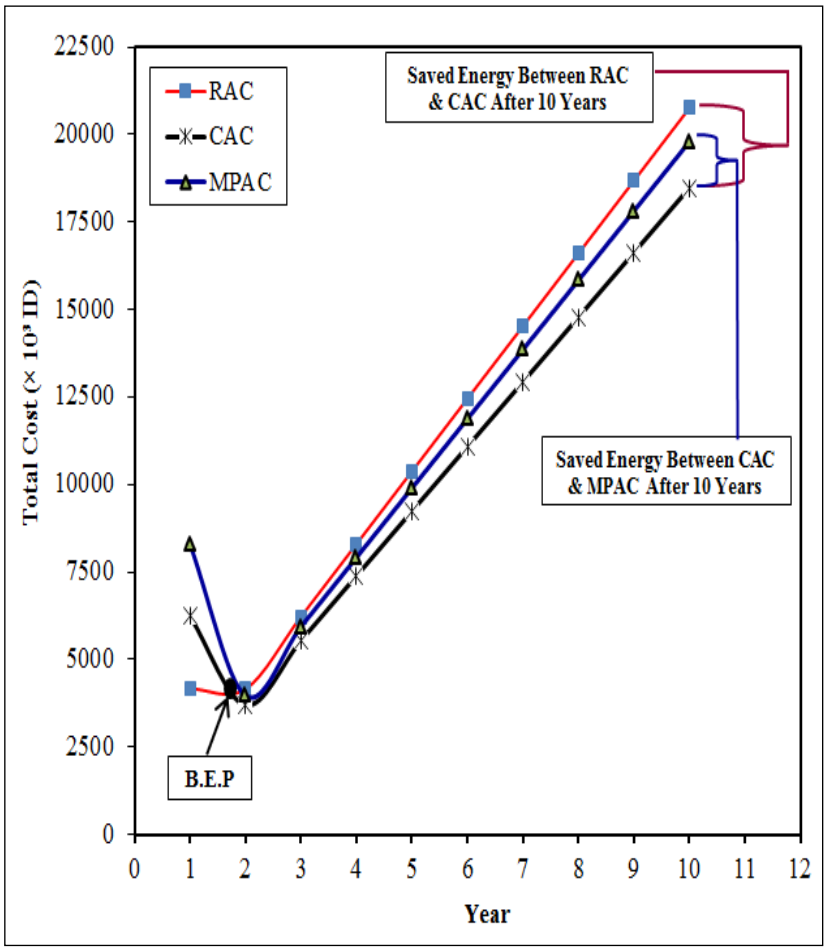


Figure (8): Life – Cycle Cost of A/C Systems for 10 years

where (BEP) the break-even point is the point at which cost are equal, there is no net loss or gain.

Results and Discussion:

In this study, RAC, CAC and MPAC systems were compared calculating initial and operating costs for a sample building located in Mosul city in Iraq , for comparison life-cycle cost analysis was used with the present-worth cost method so as to select the lower cost for life cycle ten years. It was found that the initial cost for the RAC system is lower than CAC and MPAC systems approximately 53% and 67% respectively as can be seen from tables (4), (5) and (6) with fig.(6), while the running cost for CAC system is lower than RAC and MPAC systems approximately 12% and 7% for one month as can be seen from table (7).

As can be seen from Fig.(7), the sequence of the A/C system that has lower running cost in an operational energy are CAC, MPAC and RAC systems

respectively, this means that the biggest energy consumed by the operating RAC system.

As can be seen from Fig. (8), the total cost for two systems RAC and CAC are equal after 20 months of the beginning run the two systems and after break – even point (BEP) the total cost for CAC system began to decline which indicates that there is save in electric consumption and present worth cost over a period of 10 years of operation, while the total cost for two systems CAC and MPAC are equal after 24 months of the beginning run the two systems.

Through the results mentioned above will be selected sequence the A/C systems that has lower total cost for ten (10) years as CAC, MPAC and RAC as well as the CAC system which use air duct to distribution air into each condition zone give less noise with best interior aesthetic appearance so that it fits with the interior decoration for each zone as well as the outdoor appearance because the system working for long distances and can put outdoor units on the roof of the building.

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