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Design a Central Air Conditioning System Using Variable Air Volume Type for a Hospital in Zuwarah City, Libya

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Abstract
The main objective of this paper is to design a central air conditioning system for a hospital located at Zuwarah city, Libya. Different types of air conditioning systems were studied and evaluated. Variable air volume system (VAV) had been studied in details and accordingly was selected for the hospital. The outdoor design condition had been determined according to the metrological data for the proposed site using a program called (Autodesk Revit MEP 2015).The nature, the constructions specifications of the site and the building that need to be conditioned were studied. Then; the thermal loads for the building have been calculated. The air volume flow rate was calculated as well and those calculations were essentials in the process of air duct design and duct sizing. The air duct design was obtained using two different methods (Equal Friction Loss Method, and Velocity Reduction Method). The first method was used to calculate the size of the short air ducts, and the second method was used to calculate the size of the long air ducts.
Keywords: Heating, Ventilating, and Air conditioning (HVAC) System, variable air volume (VAV), Duct Design, Autodesk Revit MEP 2015.

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تصميم منظومة تكييف هواء مركزي باستخدام تقنية تغير معدل تدفق الهواء الحجمي لمستشفى في مدينة زوارة في ليبيا

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الملخص

الهدف الرئيسي من هذا المشروع هو تصميم نظام تكييف هواء مركزي لمستشفى يقع في مدينة زوارة –ليبيا، تم في هدا البحث دراسة وتقييم مجموعة مختلف من أنظمة تكييف الهواء ومن بين هده الأنظمة تم دراسة نظام تغيير معدل تدفق الهواء الحجمي بالتفصيل وتم بعد لك اختياره واعتماده كنظام تكيف هواء للمستشفى المستهدف من الدراسة. تم دراسة الخصائص الطبيعية والانشائية للموقع والمبني المراد دراسته ثم تم تحديد درجة التصميم الخارجية بناء على بيانات الأرصاد الجوية للموقع باستخدام برنامج (Autodesk Revit MEP 2015).

تم في هده المرحلة حساب الأحمال الحرارية للمبنى، ثم بعد ذلك تم حساب معدل التدفق الحجمي للهواء والذي تم استخدامه في تصميم مجاري الهواء باعتماد طريقتين وهما (طريقة الاحتكاك المتساوي، وطريقة السرعة المتناقصة)، حيث تم استخدام الطريقة الاولى في حساب حجم مجاري الهواء القصيرة، والثانية استخدمت في حساب حجم مجاري الهواء الطويلة.

كلمات مفتاحية: أنظمة تكييف الهواء، نظام تغيير معدل تدفق الهواء الحجمي، تصميم مجاري الهواء، برنامج Autodesk Revit MEP 2015.

1. Introduction

Air conditioning is a combined process that performs many functions simultaneously. It conditions the air, transports it, and introduces it to the conditioned space. It provides heating and cooling from its central plant or rooftop units. It also controls and

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maintains the temperature, humidity, air movement, air cleanliness, sound level, and pressure differential in a space within predetermined limits for the comfort and health of the occupants of the conditioned space or for the purpose of product processing. [1] Therefore, today air conditioning has become a necessity in building, dwellings and industrial processes. [2]

Heating, ventilation, and air conditioning (HVAC) is the use of various technologies to control the temperature, humidity, and purity of the air in an enclosed space [3].

The air-conditioning system considered so far provides a single source of air with uniform temperature to the entire space, controlled by one space thermostat and one space humidistat. However, in many buildings there is a variety of spaces with different users and varying thermal loads. These varying loads may be due to different inside uses of the spaces, or due to changes in cooling loads because the sun shines into some spaces and not others. Thus, our simple system, which supplies a single source of heating or cooling, must be modified to provide independent, variable cooling or heating to each space. [4]

When a system is designed to provide independent control in different spaces, each space is calling a "zone." A zone may be a separate room. A zone may also be part of a large space. For example, a theater stage may be a zone, while the audience seating area is a second zone in the same big space where Each of them has it is owned air conditioning requirements. [4]

The need for zoning the space leads to the four broad categories of air conditioning systems, and consideration of how each can provide zoned cooling and heating. [4]

The main four HVAC system are the All-Air systems, All-Water System, Air-and-water systems, and the Direct Expansion Systems. Figure (1) shows the variable air volume system is one of the all–air system category. The variable airflow volume is achieved by

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VAV boxes. The boxes have a modulating damper that throttles in response to the thermostat setting. When the indoor temperature conditions vary from the set point, the VAV box damper responds by restricting or increasing the supply air volume to the space. [5]
VAV systems are suitable for use in buildings having many areas of dissimilar cooling requirements. VAV systems lead to significantly lower power consumption, especially in perimeter zones where variations in solar load and outside temperature allows for reduced air flow rates. [5]
The typical local controls in a valuable air volume (VAV) air-conditioning system rely on static pressure control, supply air temperature, and outdoor air flow [6]. These local controls have an effect on the indoor comfort and energy consumption in the system. The appropriate controls can be achieved by adopting indoor loads and outdoor conditions in real time. [7]

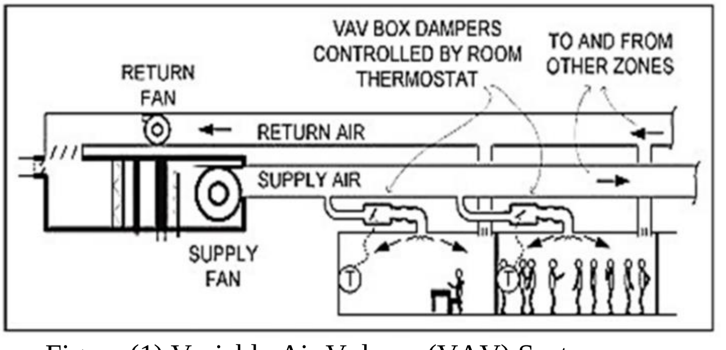

Figure (1) Variable Air Volume (VAV) System

2. Characteristics of the Proposed Project

In 1937, ASHRAE guide introduced a systematic method of cooling load Calculation involving the division of various load components. In the ASHRAE Guide, solar radiation factors were introduced and their influence on external walls and roofs was taken into consideration. Both the window crack and number of air changes methods were used to calculate infiltration. [8]

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In 1980, the U.S. Department of Energy sponsored a computer program for energy estimation and load calculation through hour-by-hour detailed system simulation, which was published through Los Alamos National Laboratory and Lawrence Berkeley Laboratory. In this program, a custom weighting factor method for various room configurations is used for heating and cooling load calculations. Many computerized thermal load and energy calculating software programs had been developed in the 1980s. Since the 1980s, because of the wide adoption of personal computers, the use of computer aided HVAC design was rapidly increased and many thermal load and energy analysis programs were developed in this period. [8]
HVAC systems in health care facilities provide a broad range of services in support of populations who are uniquely vulnerable to an elevated risk of health, fire, and safety hazard. These heavily regulated, high-stakes facilities undergo continuous maintenance, verification, inspection, and recertification; typically operate 24 hours/day, 7 days/ week, and are owner-occupied for long life cycles. [8]
In support of the health care process, HVAC systems are called upon to perform several vital functions that affect environmental conditions, infection and hazard control and building life safety. Staff and patient comfort, and the provision of therapeutic space conditions, facilitate optimum patient treatment outcomes. [8]

3. Purpose of Cooling Load Calculations

It's meant by conditioning a space to provide a comfort conditions to this space, so the heat that generated into the space must be removed. To remove that heat a suitable air conditioning machine will be used. By calculating the cooling load or the heat that must be removed the air conditioning machine power will be specified. Outside weather conditions and the sun combines to produce a cooling or heating load through the building envelop. [9]
The load calculation depends on

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3.1. The thermal characteristics of the walls, roof fenestration, floor, interior building furnishings, construction, people capacity and ventilation.

3.2. Heat transfer resulting from the difference between the external conditions and internal conditions, and the impact of solar energy. [9]

4. Design Conditions

A purpose of heating, ventilating and air conditioning systems is to provide conditions for human comfort, so the indoor conditions must provide the thermal comfort for the human. In the design procedures the outside conditions must be known as well. Therefore; the metrological data must be known for the proposed site which is (Zuwarah City, Libya).

4.1. Indoor Design Conditions

Thermal Environmental Conditions for Human Occupancy, defines thermal indoor conditions that is a majority of occupants will find comfortable(ASHRAE). The inside design condition used in this project and set out in a table (1) are based on the recommendation of ASHRAE Handbook.

Table (1) The inside design conditions used in this project

Application	Design Temperature (c^o)		Design Humidity (RH%)	
	Used in this research	ASHRE Recommended	Used in this research	ASHRE Recommended
Offices, waiting, nurse, patient Dining room	23	22-24	44%	30-60%

4.2. Outdoor Design Conditions

The outside design conditions used in the calculation were chosen based on the building location. The closest weather station is selected along with its weather data.

For the cooling loads calculation, the design temperature a maximum dry-bulb temperature corresponding to the 1% monthly

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percentile temperature for the location. This is the temperature that is exceeded on average, during that month, for 1% of the time. The daily range and profile of the dry-bulb temperature, and the corresponding values of wet-bulb temperature, are derived from data in the ASHRAE database. The clearness number is defined (the ratio of the direct normal irradiance calculated with local mean clear-day water vapor divided by the direct normal irradiance calculated with water vapor according to the basic atmosphere dimensionless) is currently set to 1 for all locations.
For the heating loads calculation, the design outside dry-bulb temperature is set to the 99% annual percentile temperature for the location -the temperature that is exceeded on average over a period of years for 99% of the time. [10]
Table (2) demonstrates the outdoor design conditions fortheproposed location for both heating and cooling condition. In addition, figure (2) shows the monthly design data for the same location.

Table (2) The Outdoor Design Conditions

Outdoor conditions		Heating	Cooling
Dry bulb Temp.	[°C]:	6	39
Wet bulb Temp.	[°C]:	4	29
Relative Humidity	[%]:	86.3	25.9
Daily range	[°C]:		13.8

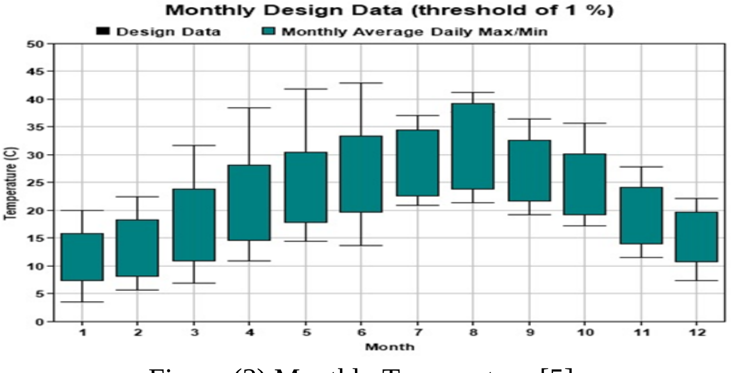

Figure (2) Monthly Temperature [5]

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5. Project Information

The project is located in the city of Zuwarah, Libya. The building is a hospital with 31 rooms with a capacity of 110 shelter beds, 13 doctors and nurses' rooms, 8 services rooms, and 4 restaurants with a capacity of 200 people.

6. Location and Orientation

Table (3) shows the project location information.

Table (3) Project Location

City	Zuwarah
Elevation	80.77 [m]
Latitude	32.93 [°N]
Longitude	12.09 [°E]

The building is headed to the north-east direction, where all exterior walls exposed to the sun, except the south-west wall. The figure (3) shows the building orientation.

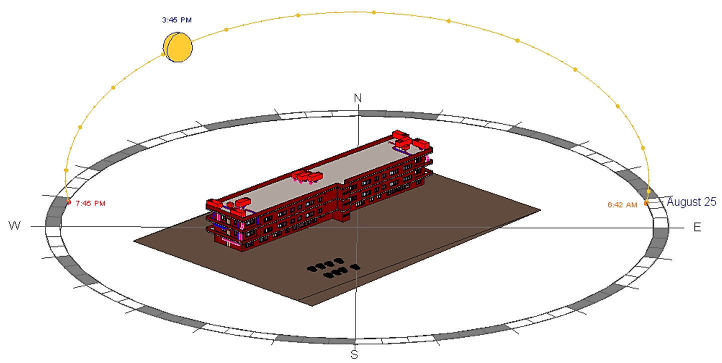

Figure (3) Orientation of the Building [10]

7. Characteristics of Building Construction and wind speed distribution

Several design parameters have a significant effect on the heating and cooling thermal loads of buildings. These parameters include features of the building envelope such as building shape and

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orientation, wall and roof constructions, window types and sizes, as well as characteristics of heating, ventilating, and air conditioning (HVAC) systems such as their type, efficiency, and operation settings. [11]

Roof, ground floor, external wall, internal wall 10, internal wall 15, internal floor, glass, Windows, Glazed Walls and Doors were all considered and their material specifications (overall heat transfer coefficients,Thickness,Conductivity, and Density) were defined in details. In addition, the average wind speed and its direction were determined in order to take it into consideration during the cooling load calculation process.

The figure (4) demonstrates the wind speed distribution of the proposed location.

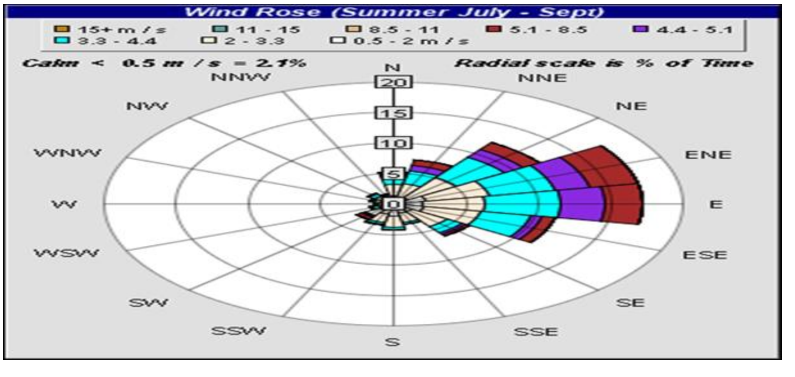

Figure (4) Wind Speed and its Direction [5]

8. Main Components of Cooling Load Calculations

Cooling load calculations supplied air to the building are mainly used to determine the volume flow rate of the air, as well as the size of the HVAC equipment needed.

Cooling load sources usually can be classified into two categories. External cooling loads sources and internal cooling loads.

8.1. External cooling loads are formed because of heat gains in the conditioned space from external sources through the building

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envelope or building shell and the partition walls. Heat gain entering from the exterior walls and roofs, Cooling load through interior surfaces, Solar heat gain through glass, heat gain entering from the partition walls and interior doors, Infiltration of outdoor air into the conditioned space and Ventilation are all the components of external cooling loads sources.

Beside the mentioned external cooling load sources, there are several factors were taken into account to achieve an optimum result.

8.1.1 The existence of curtains on all the windows of the building which reduces the heat generated by the sun's rays.

8.1.2 Dropout rate is small due to the presence of marble encases aspects of doors and windows, which are themselves made of insulating materials reduce the dropout rate.

8.1.3 Existing for double acting door of the main entrances reduces the air leakage to the outside.

8.2.Ventilation

Outdoor air must be introduced to ventilate conditioned space. Ventilation air is normally introduced at the air conditioning apparatus rather than directly into the space. ASHRAE recommends minimum ventilation rate for most common applications. For general application, such as hospital healthcare, 13 L/s per person is suggested.

For each room 10% fresh air and withdraw the exhaust air through single duct to flush out the polluted air.

8.3. Internal Cooling Loads Sources

These loads are formed by the release of sensible and latent heat from the heat sources inside the conditioned space. People, Electric lights, and Equipment and appliances are forms of internal cooling loads.

In order to obtain the optimum results for internal cooling load calculations, the operating hours of light and equipment of the building and presence periods of people in the building were

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estimated based on standard building operation Schedules which is illustrated in table (4). [12]

Table (4) Building Operating Schedules [10]

Hours																							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Person - typical day (%)																							
75	75	75	75	75	75	75	75	100	100	100	100	100	100	100	100	100	100	100	100	100	75	75	75
Light - typical day (%)																							
25	25	15	15	25	50	100	100	100	100	50	25	25	25	25	25	25	25	50	50	100	100	100	50
Equipment - typical day (%)																							
75	50	50	50	50	75	75	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	75

9. Duct Design & Duct Sizing

The purpose of air conditioning ductwork is to deliver air from the fan to the diffusers which distribute the air to the room. Air Moves through the Ductwork in response to a pressure difference created by the Fan. The necessary pressure difference will be a function of the way the ductwork is laid out and sized. The objective of duct design is to size the duct in order to minimize the pressure drop through the duct, while keeping the size of the ductwork to a minimum. Proper duct design requires knowledge of the factors that affect pressure drop and velocity in the duct. Moreover, it requires the knowledge of the duct system components. Vibration absorber, Take-offs, duct fitting and accessory, dampers, terminal units, and air terminals are all the duct system components.

The main goal of HVAC design systems is the use of the duct at the lowest cost. Installed and operating cost considerations dictate that duct systems must be designed to operate at the lowest possible static pressure and low flow speed for quiet and economical operation. There are several methods to calculate the size of the duct, and the best-known methods are the equal friction loss method, and velocity reduction method. [12]

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9.1. Equal Friction Loss Method

Equal friction method is simple and is most widely used conventional method. This method usually yields a better design than the velocity method as most of the available pressure drop is dissipated as friction in the duct runs, rather than in the balancing dampers. This method is generally suitable when the ducts are not too long. However, the principle of this method is to make the amount of loss of pressure in the unit of the length equally in all parts and branches of the duct, the friction loss per linear meter (Pa / m) for each main or branch ducts within the limits of 0.8 to 1.2 (Pa / m). This method is used in simple network, and usually used in the return air and exhaust ducts. [12]

The maindisadvantage of Equal friction duct design is not recommended for VAV systems, because static pressures throughout the duct system cannot be balanced.

9.2. Velocity Reduction Method

The velocity criterion for sizing duct is fairly simple and straightforward. The duct system is designed to provide progressively lower duct velocities as the air proceeds from the main duct to the branches. The various steps involved in this method are:

9.2.1. Selecting suitable velocities in the main and branch ducts.

9.2.2. Finding the diameters of main and branch ducts from the airflow rates and velocities for circular ducts. Subsequently, the cross-sectional area for the rectangular ducts can be determined from the flow rate and velocity, and then through fixing the aspect ratio, the two sides of the rectangular duct can be calculated.

9.2.3. From the velocities and duct dimensions obtained in the previous step, the frictional pressure drops for main and branch ducts using friction loss chart or equation can be calculated.

10. Design of HVAC System using Autodesk Revit MEP

Autodesk Revit is building information modeling (BIM) software for architects, structural engineers, MEP engineers, designers and

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contractors. It allows users to design a building and structure and its components in 3D, annotate the model with 2D drafting elements, and access building information from the building model's database. Revit is 4D capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later demolition. [13]

By adopting BIM, MEP firms can use this consistent information throughout the process to design and document innovative projects, visualize appearance accurately for better communication and simulate real world MEP system performance for better understanding of cost, scheduling and environmental impact. [13]

Autodesk Revit MEP provides mechanical, electrical, and plumbing (MEP) engineers with tools to design even the most complex building systems. Revit tools enable design that is more accurate, analysis, and documentation of efficient building systems from concept through construction. [13]

Design mechanical systems, such as duct system, to meet the heating and cooling demands of the building. Create duct systems using tools to place air terminals and mechanical equipment in a project and Using automatic system creation tools to create duct routing layouts to connect the supply and return system components are all can be defined as capabilities of the Revit MEP. [13]

Three-dimensional modeling for ductwork and piping enables users to create HVAC systems that can be shown clearly using color schemes for design airflow, actual airflow, mechanical zones and more. Create electrical color schemes for power loads, lighting per area and more. [13]

11. Duct and Pipe Sizing/Pressure Calculations

With built in calculators in Autodesk Revit MEP software, engineers can perform sizing and pressure loss calculations according to industry standard methods and specifications, including the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) fitting loss database. System sizing tools instantly update the size and design parameters of duct

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and pipe elements without the need for file exchanges or third-party applications. Select a dynamic sizing method for the ductwork and piping systems in your plans using duct sizing and pipe sizing tools, including friction, velocity, static regains and equal friction sizing method for duct sizing, and velocity or friction method for pipe sizing. The heating and cooling load analysis in Revit MEP uses a Radiant Time Series (RTS) method. [13]. Figure (5) presents a flow chart of cooling loads calculation in Revit Program.

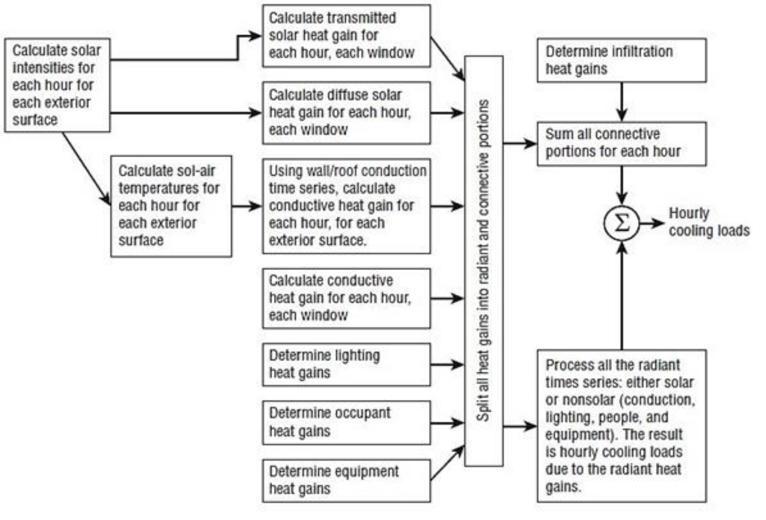

Figure (5) Flow chart of cooling loads calculation in Revit MEP Program [13]

Radiant Time Series (RTS) method is the method using to determine the building and space peak heating or cooling loads. This method takes into account the time-delay effect of heat transfers through building envelopes, from the outside, and into spaces.

The RTS calculation method determines cooling loads based on an assumption of steady periodic conditions, such as occupancy, design-day weather, and cyclical 24-hour heat gain conditions. [13]

Two time-delay effects are addressed during cooling load calculations:

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11.1. Delay of conductive heat gain through opaque massive exterior surfaces, such as exterior walls, the building roof, and floor slab on or below grade.

11.2. Delay of radiative heat gain conversion to cooling loads.

4. HVAC System Design Approach

First step of designing the system was through intoducing the architectural design of the proposed site (The Hospital), to the software tools, this was obtained from Rakaez Company of Engineering Consultant. The proposed site is consisting from three floors, as shown in Figures (6,7).

Figure (6) Ground Floor of the Hospital

Figure (7) First and second Floor of the Hospital

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Secondly, the construction physical properties for the building, which include the specification of the walls, floors, Ceilings, windows and doors were defined. Beside the previous, a consideration should be taken into account which is the similarity between the 1st, and 2nd floor of the building. where; the ground floor is considered different from the 1st, and 2nd floor. Afterward, the metrological data (Temperature, Humidity) of the site of the hospital was determined using an interactive map through the Google Maps service. This step is accomplished through entering the exact address of the hospital using the latitude and longitude of the building that demonstrated in the table (3). Subsequently, the spaces of the building are defined in terms of spaces type, and its characteristics. finally, the capacity, and assigning name for each space were done. The purpose of these definitions is to calculate the cooling load for each space.
Dividing each floor of the building into three zones was made as shown in Figure (8), based on the similarity of spaces that compound a zone, and the capacity of the rooftop unit.

Figure (8) Design Zones

Moreover; an extra zone was made to include the restaurant and its kitchen in the first and second floors, in addition; the spaces of each zone were linked in this step to design the ducts that took into

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account the available space between ceiling and the suspended ceiling. Finally, an indoor design condition for each zone was entered based on ASHRE standard recommendation.

In order to determine the infiltration rate of this building. An inspection has been done to evaluate the condition of the building, in terms of the structure cracks that might outside air infiltrates through it, and the openings of windows, doors, and…. etc. The Revit provides three options to design the infiltration rate of the building. These options are depending on the condition of the building and they are as follows:

- Loose: 0.076 CFM/ft2 of outside air.
- Medium: 0.038 CFM/ft2 of outside air.
- Tight: 0.019 CFM/ft2 of outside air.
- None: Infiltration air excluded from the load calculation. [13]

For this project, the option was taken to be "Tight". This selection was taken based on the building structure, and type of doors and windows used in this building.

5. Results and Discussion

Cooling load Calculations were done based on the information provided in the previous section, and the results were Summarized in table (5), table (6) and table (7).

Table (5) Project Summary

Location and	
Project	Hospital
Address	Zuwarah , Libya
Calculation Time	Monday, March 28,
Report Type	Simple
Latitude	32.93°
Longitude	12.09°
Summer Dry Bulb	39 °C
Summer Wet Bulb	29 °C
Winter Dry Bulb	6 °C
Mean Daily Range	6 °C

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Table (6) Building Summary

Inputs	
Building Type	Hospital or Healthcare
Area (m²)	3,733
Volume (m³)	9,934.64
Calculated Results	
Peak Cooling Total	1,561.6
Peak Cooling Month	August 1:00 PM
Peak Cooling	985.4 (KW)
Peak Cooling Latent	576.2
Maximum Cooling	1,417.2
Peak Cooling	47,793.5
Peak Heating Load	553.6
Peak Heating Airflow	23,199.1
Cooling Load	418.30
Cooling Flow	12.80
Cooling Flow / Load	30.61
Cooling Area / Load	2.39
Heating Load	148.29
Heating Flow	6.21

Table (7) Loads of each zone

Name	Calculated Supply Airflow	Calculated Cooling Load	Calculated Heating Load
Bathroom	5706.1 L/s	268.6 KW	129.4 KW
Ground Floor			
Laboratory	5063.7 L/s	237.5 KW	114.4 KW
Left Zone	3866.0 L/s	93.3 KW	32.3 KW
Med Zone	3801.2 L/s	94.9 KW	33.6 KW
First Floor			
Left Zone	3981.3 L/s	88.1 KW	28.7 KW
Right Zone	4612.9 L/s	105.6 KW	34.6 KW
Med Zone	4458.9 L/s	99.7 KW	32.9 KW
Left Canteen	1771.5 L/s	73.4 KW	25.5 KW

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Right Canteen	1698.6 L/s	62.3 KW	25.4 KW
Second Floor			
Left Zone	3926.3 L/s	89.3 KW	29.5 KW
Right Zone	4608.0 L/s	106.0 KW	34.8 KW
Med Zone	4298.9 L/s	98.4 Kw	32.5 KW

A square ceiling diffuser was distributed through the ceiling of the space based on the calculated airflow supply which was determined from the Cooling Loads Calculation. The VAV air conditioning system type was chosen for this project, because it has advantage of more control of the temperature over the other type. Figure (9), shows the procedure of connecting the supply air to the space trough a VAV devices; which is connected through a circular duct instead of rectangular duct for the following reasons:

- The circular ducts have less pressure drop than the rectangular ducts.
- The flexible of circular duct over the rectangular ducts, where the circular ducts can be used in places where the other types fail.

Then; Linking VAV devices on the main duct connecting to air condition machine (Rooftop).

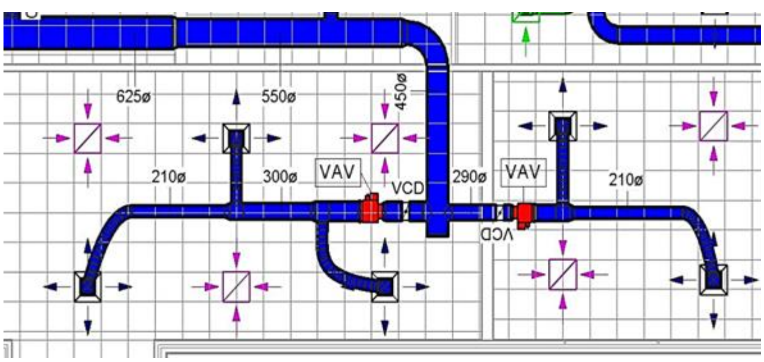

Figure (9) Distribution of Supply Air Diffuser and VAV Boxes

Due to the small distance available between the ceiling and the suspended ceiling. The return air plenum design certified (2015

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ASHRAE Handbook – HVAC Applications), was used instead of a return ducts which need larger spaces, or distances. The Air supply diffusers distributions for each space (patient room, nurse room, services… etc.) is shown in figure (9) as was mentioned in previous steps. In addition; the return and fresh air ratio was determined to be 90% according to the (ASHRAE standard) for the (patient room, nurse room, services, corridor), meanwhile the restaurant and laboratory according to the same standard, they need only a fresh air (100% fresh air) due to health care issues. Therefor; the air inside these spaces will be expelled out through the air expulsion slots connected to the exhaust fans as shown in Figure (10).

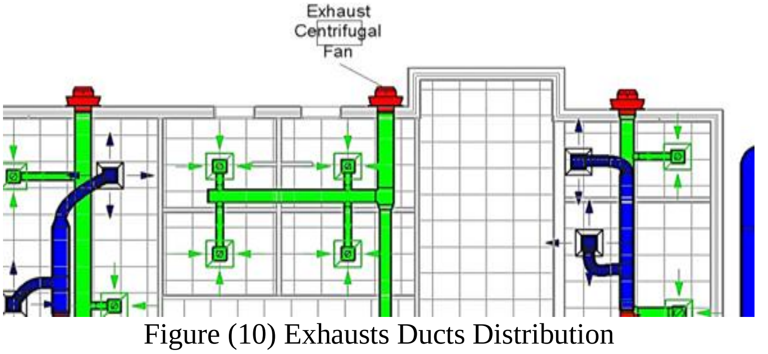

Figure (10) Exhausts Ducts Distribution

Bathrooms of the entire hospital were conditioned in the same manner of the restaurant, and kitchen. Where in Bathroom contamination air is flushed out through exhaust ducts that supplied with an exhaust fan as shown in Figure (10). Figure (9) demonstrates the volume control damper (VCD) installed in the branches of main ducts. These dampers are used to increase in the process of airflow adjustment, so they make sure the same airflow enters to each space. After the completion of the process of connecting air supply duct to each zone separately, and connecting the expulsions ducts, the dimensions of the supply duct were calculated according to (Velocity Reduction Method) due to the long length of the main duct and the velocity in the ducts was chosen according to the ASHRE

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recommended values that will be 7.5 m/ s for supply duct and 6.5 m/s for return duct. The dimensions of the expelling ducts were calculated using (Equal Friction Method) due to the small length of the duct, and the value of the friction factor used is (0.82 pa\m). [11]
Insulating the external supply ducts with Fiber Glass thermal insulation which has properties of 25 mm thickness, 10 – 96 kg\m3 density, and 0.032 W\m. K Thermal conductivity was chosen as an insulating material due to their decent properties.
The final duct design of the hospital is illustrated in figures (11), (12), and (13) for separate floors and the entire building.

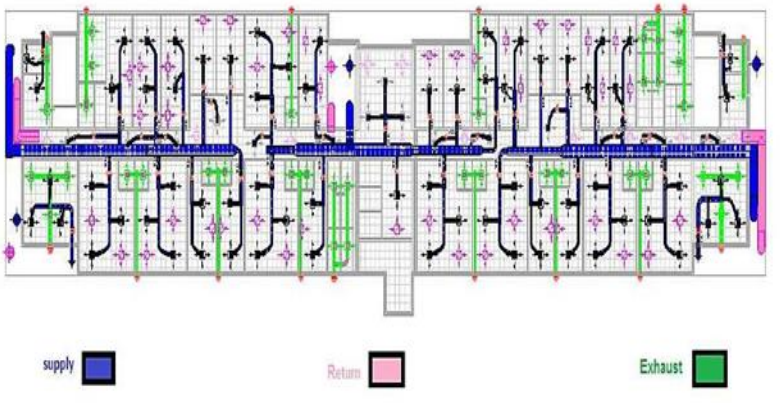

Figure (11) Ground Floor Duct Design

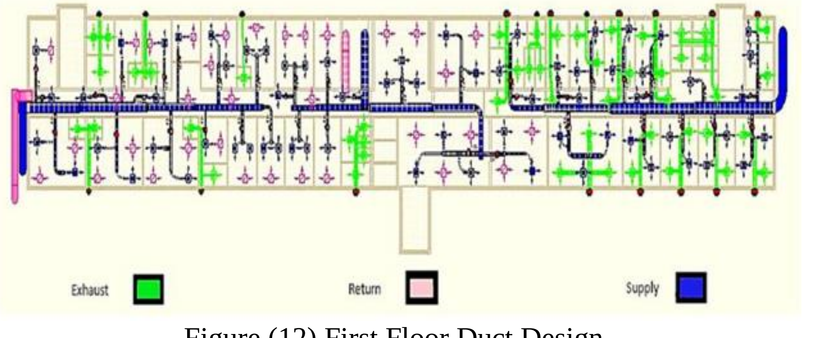

Figure (12) First Floor Duct Design

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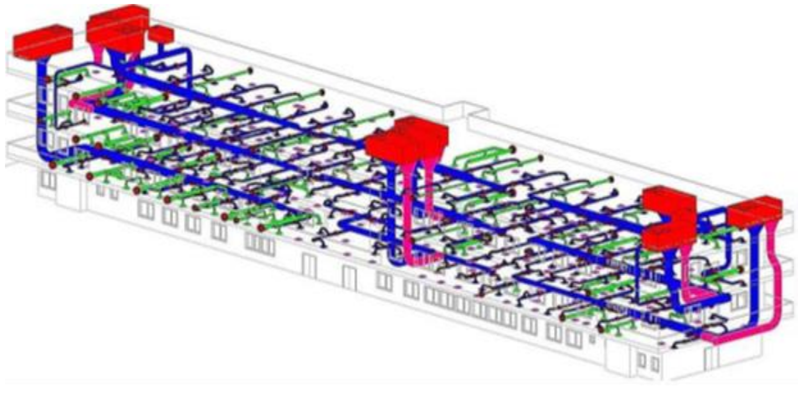

Figure (13) 3D Model of Building Design

6. Conclusion

After couple of months of working on this research, different types of air conditioning systems were known and studied. In addition, the nature, the specifications, and the site of the building that need to be conditioned were studied. Revit MEP software has been used in order to determine the cooling outdoor design temperature, which was the Dry Bulb 39Co, Wet Bulb 29 C^{o}, and the inside design temperature was 23 C^{o} which was obtained using ASHRAE climate data standard.

According to the input data (structure characteristics, indoor design requirements, site location and orientation) the building thermal cooling loads were calculated and the results turned up to be building Peak Cooling loads (Total Load) is 1,561.6 (kW) and Peak Cooling Airflow 47,793.5 (L/s). Those results were considered to be satisfactory and reasonable when they had compared with ASHRAE estimation standards.

The central air conditioning system was designed using VAV system. The achieved results were satisfied in the all manners of the design, for example the air velocity in the duct, and the duct dimensions were reasonable compared to the ASHRAE's Standards.

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