

## A Comparative Study for the Traditional and Modern Houses in Terms of Thermal Comfort and Energy Consumption in Umm Qais city, Jordan

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### ABSTRACT

This research presents a comparison study between the vernacular architecture represented by the heritage houses (Fallahy Houses) and the typical contemporary houses in Umm Qais city in the northern part of Jordan, in terms of thermal performance. It analyzes the parameters of the heritage houses to explore the impact on the human thermal comfort and energy consumption compared with the typical modern houses. The study investigates the performance of the vernacular houses and how they respond to the physical and climatic conditions. It also shows how these houses depend on passive design to control solar gains, and decrease heating and cooling loads keeping a good level of thermal comfort inside. The study compares these vernacular houses with the traditional contemporary house in Umm Qais. The selected samples from each type of houses were taken to evaluate the impact of the vernacular principles of design, building construction and materials on the thermal performance and the thermal comfort inside the houses. Computer simulation, accompanied with measuring tools and thermal cameras, was used for thermal analysis in the selected houses. Revit software was also used for this purpose to validate the results and compare it with the real field results. The results show that the passive design strategy in the vernacular houses is substantial and more effective than the techniques used in the modern houses.

**Keywords:** vernacular architecture, Fallahy Houses, Umm Qais, thermal comfort, design strategy

### INTRODUCTION

Through examining the vernacular architecture related to environmental issues, it is clear that humans should make all their design decisions suitable for the global natural system. Accordingly, the architecture that respects the contextual considerations and deals with natural surroundings can achieve a highly health and comfortable architectural environment (Lee et al., 1996, Magliocco et al., 1999).

Vernacular architecture involves the harmonization between the buildings with their region, natural resources, climate, culture, religious and human beings. It has architectural and constructional techniques developments through several years by trial and error (Fathy, 1986).

The improved vernacular passive principles can be integrated into building design to produce more

satisfactory and low energy buildings (Foruzanmehr, 2015, Wang, 2016, Keshtkaran, 2011).

On the other hand, the typical present-day architecture does not pay attention to utilize passive systems and techniques for enhancing the indoor environments (Cantin, et al., 2010, Zhai and Previtali, 2010). In residential buildings, the lack of concern to environmental design principles causes an unsatisfactory level of indoor thermal comfort (Al Zoubi, et al., 2008, Al Zoubi and Almalkawi, 2014).

The trend towards adopting modern materials without taking into consideration the thermal efficiency of these materials in terms of the indoor thermal comfort leads to many problems in the environment (Al Zoubi, et al., 2008,, Kim, 2005).

In addition, non-climatic design responsibility of building brings out an increase in their energy

consumption (Al Zoubi, et al., 2008, Al Zoubi and Almalkawi, 2014, Al Zoubi and Al-Shboul, 2012).

Vernacular architecture in Jordan originates from various regional, social, and cultural factors. It is formed in different sites to meet the climatic conditions and topographical needs (Khammash, 1986).

Umm Qais, considered in this research, has a dry-warm climate according to its geographical locations. The vernacular architecture seems in its dwellings and harmony relationship with their surroundings and nature to attain good living conditions for their inhabitants.

Most of studies in Jordan have been done to describe the traditional dwelling types and their architectural features; however, few of them analyze the parameters of the vernacular dwellings to explore the impact on the human thermal comfort and energy consumption compared with the contemporary dwellings.

Therefore, this research aims to investigate the performance of vernacular houses in Umm Qais village, and how they respond to its physical and climatic conditions. It also shows how these houses depend on passive design to control solar gains, as well as decrease heating and cooling loads maintaining a good level of thermal comfort inside the space. The study compares these vernacular houses with the traditional present-day house in Umm Qais. It focuses only on the building construction materials, the wall thickness and the ratio of window size to the wall area.

## UMM QAIS

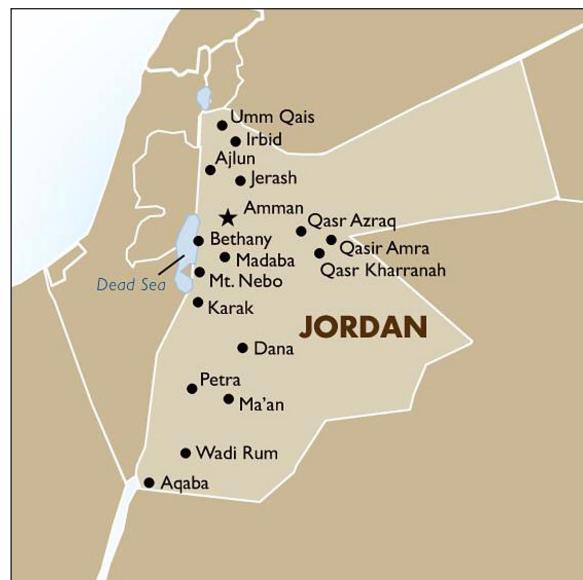
### Location and history

Umm Qais (Gadara) is a town in northern Jordan. It is located at (32°39' 23" N, 35°40'41" E) with altitude at 378 m above sea level (Ministry of Tourism and Antiquities, 2018). It has best view overlooking the Jordan River, Tiberias Lake, and the Golan Heights (Figure 1) (El Khouri and Omoush, 2015).

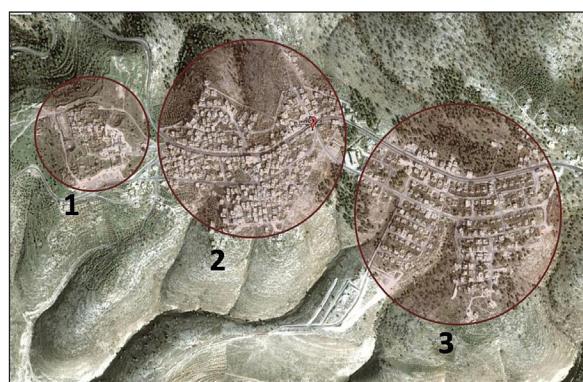
As shown in (Figure 2 and 3) Umm Qais grew up and expanded over the past decades. It has an archaeological site including historical ruins and Ottoman village (Heritage vernacular houses). It also has a modern part which is called the modern village, expanded from the old town, with modern houses with fully rural farms around them (Segal, 1988).

### Umm Qais Vernacular Village

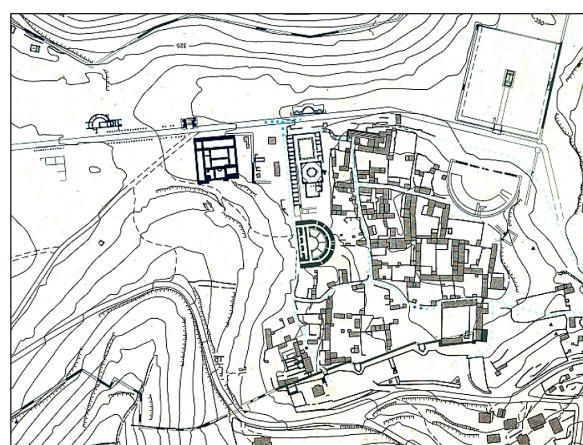
The ancient city of Um Qais (called *Gadara* during the Roman era) has been resettled by



**Figure 1.** Map of Jordan, location of Umm Qais (<https://www.goway.com/travel-information/africa-middle-east/jordan/introduction/>)



**Figure 2.** A Satellite image of Umm Qais village. 1. Archeological site including historical ruins and Ottoman village (Heritage vernacular houses), 2. Modern village expansion, 3. Umm Qais modern houses (Google Earth, 2018)



**Figure 3.** A map shows the Archeological site and heritage vernacular dwellings (Ministry of Tourism and Antiquities, 2018)

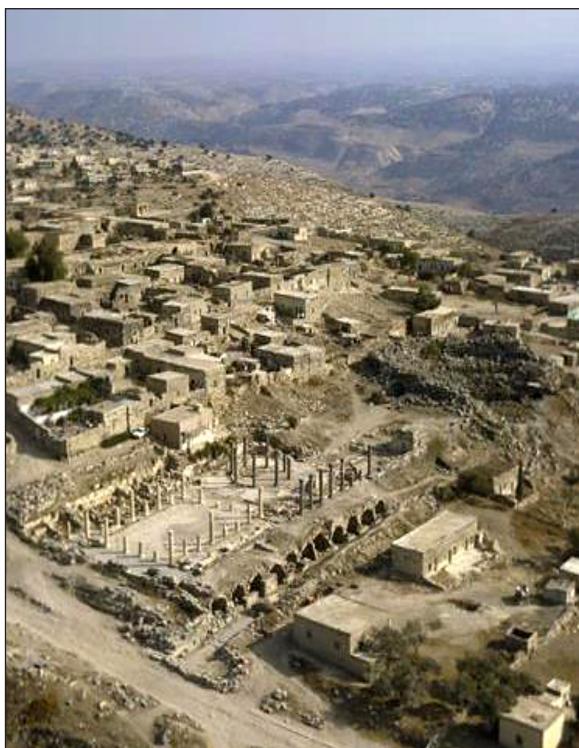
inhabitants from the neighbouring villages, such as Malka and Sama Al-rousan since the 19<sup>th</sup> century as shown in Figure 4, 5, and 6. Gadara city architecture was influenced by the Greco-Roman city, but later the city formed its own layout from local vernacular features and demands (Ministry of Tourism and Antiquities, 2018).

In 1967, the Jordanian Department of Antiquities planned to invest more in the ancient city of Gadara and extract the Greco-Roman style at the expense of the Ottoman village. Because of that the Department of Antiquities put the hand on the houses and lands in the old city pushing the inhabitants to move to a new housing project outside the ancient city. After the expropriations of houses and lands, they began archaeological excavations for the historical Roman period.

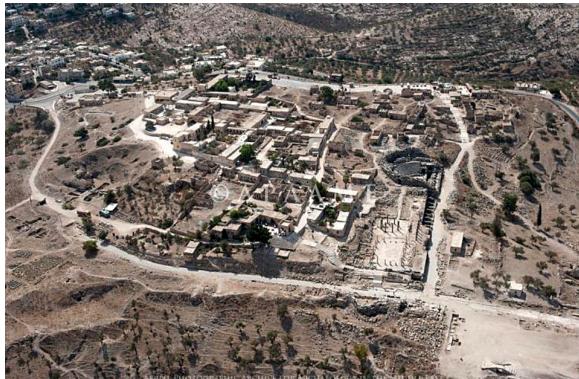
The new housing project was built in 1976 as a compensation for the people moved from their homes, see Figure 7. The project area of the housing project was about 46 hectares of the agricultural lands in the town. These new houses were very small compared to their old houses. Many large families were forced to split into different houses as a result of the inappropriate design for these families. Moreover, they had to leave numerous cultural and work traditions (e.g. keeping animals, farming and cultivating olive trees away from them). Due to these reasons, many people lost their annual wages and were obliged to search for low-paying jobs in nearby urban areas such as Irbid city (HUDC, 2018).

## RESEARCH METHODOLOGY

In order to investigate the problem in the above-mentioned changes in Umm Qais in terms of the environmental conditions, selected samples from each type of dwellings, vernacular and present day, were taken to evaluate the impact of the



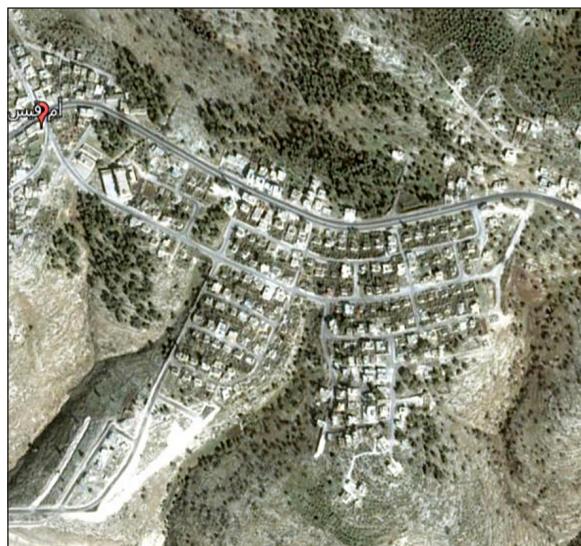
**Figure 4.** The heritage vernacular dwellings are on the upper part of the Greco-Roman City (<https://mapcarta.com/34604814>).



**Figure 5.** An Arial view shows the urban fabric of the old Umm Qais (<http://www.soniahalliday.com>)



**Figure 6.** A different view from Roman Theatre towards the Ottoman village (the old Umm Qais) (Google earth, 2018). 2.3. Umm Qais Modern Housing



**Figure 7.** A satellite view of Umm Qais modern housing

vernacular principles of design, building construction, and materials on the energy analysis.

Although there have been many variables to compare between the vernacular architecture and the typical contemporary dwelling in Umm Qais city in terms of the thermal performance and the

thermal comfort inside the dwellings, this research was focused only on the building typologies, building envelope including the materials, and building construction in ground floors, walls and ceilings, as well as the thickness of each layer.

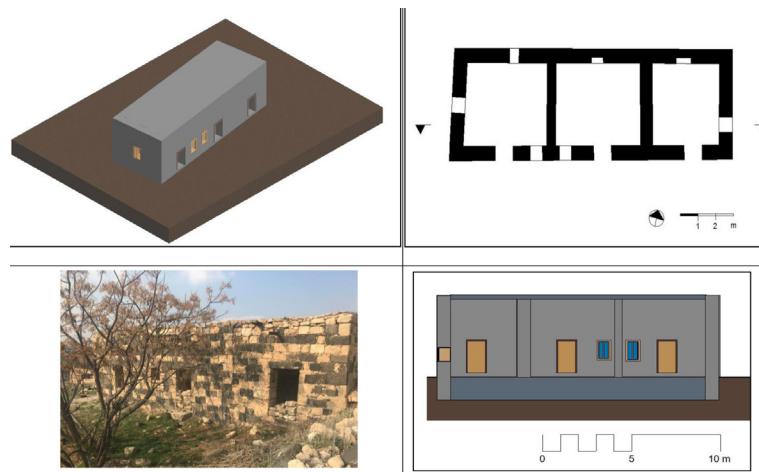
### Umm Qais vernacular dwellings

The two samples of vernacular dwellings under study are located in the Ottoman settlement of Umm Qais (Figures 4, 5). The first one is a triple-space dwelling and the other one is single-space dwelling (Figure 8 and 9).

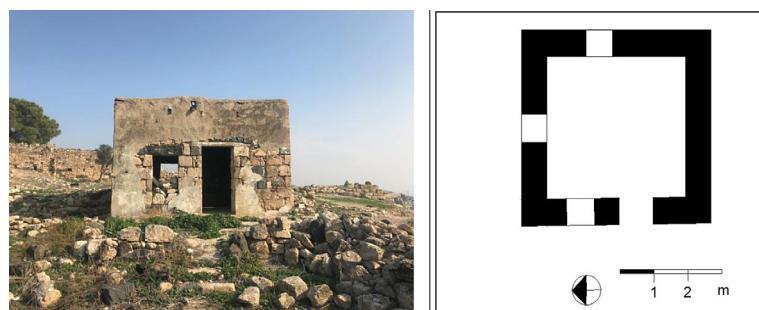
The dimensions of the spaces with the thermal properties of the door used in this research are illustrated in Tables 1 and 2. In addition to the construction materials and windows of the simulated dwellings with their thermal properties are shown in Tables 3 and 4.

### Umm Qais typical present-day dwellings

Umm Qais modern housing project is divided into two types of dwellings; the first one is 50 units from class A with 106 m<sup>2</sup> in area, and the second is



**Figure 8.** A triple-space dwelling. (A) 3D modeling view, (B) Plan layout, (C) External shot, and (D) Cross-section



**Figure 9.** A single-space dwelling. (a) External shot, (b) Plan layout

**Table 1.** Dimensional analysis of the vernacular dwelling under investigation

Type	Area of spaces ( m <sup>2</sup> )	Height (m)	Windows Position- Size ratio (%)
Triple- space	20	4.7	SW: 3.4% NW: 1.8% SE: 3.7%
	20	4.7	SE: 3%
	16	4.7	NE: 2.3%
Single-space	16	4	W: 5.5%
			N: 3.5%
			E: 3.6%

**Table 2.** Thermal properties of the doors used in vernacular dwelling (Al Zoubi, H. et al., 2008).

Materials	Thickness (cm)	Conductivity (W/m <sup>2</sup> °C/m)	Specific heat (Kcal/kg °C)	Density (kg/m <sup>3</sup> )
high wood density	5	0.37	0.13	1000

**Table 3.** The material's thermal properties used in vernacular dwelling

Type	Materials	Thickness (cm)	Conductivity (W/m <sup>2</sup> °C/m)	Specific heat (Kcal/kg °C)	Density (kg/m <sup>3</sup> )	U-value (W/m <sup>2</sup> °C)
Wall	Lime stone	0.025	1.3	0.217	2560	1.2764
	Stone	30	5	0.2	2480	
	Clay	10	0.16	0.22	1600	
	Stone	30	5	0.2	2480	
Ground Floor	Earth	99	1.4	0.215	1301	0.5009
	Gravel jeer	45	0.38	0.235	1401	
	Base coarse stone	10	1.51	0.231	2050	
	Sand	45	0.42	0.239	1800	
	Cement mortar	3	0.931	0.292	1850	
Roof	Wood (oak)	5	0.17	0.48	850	1.0188
	Reed	3	0.056	0.7	225	
	Mud	15	1.1	0.35	1840	
	Lime stone	2	1.3	0.217	2560	

**Table 4.** The vernacular dwelling window's properties

Materials	U-value (W/m <sup>2</sup> °C)	G-value	T-sol	Specific heat (Kcal/kg °C)
Single glass	5.88	0.636	0.45	0.2

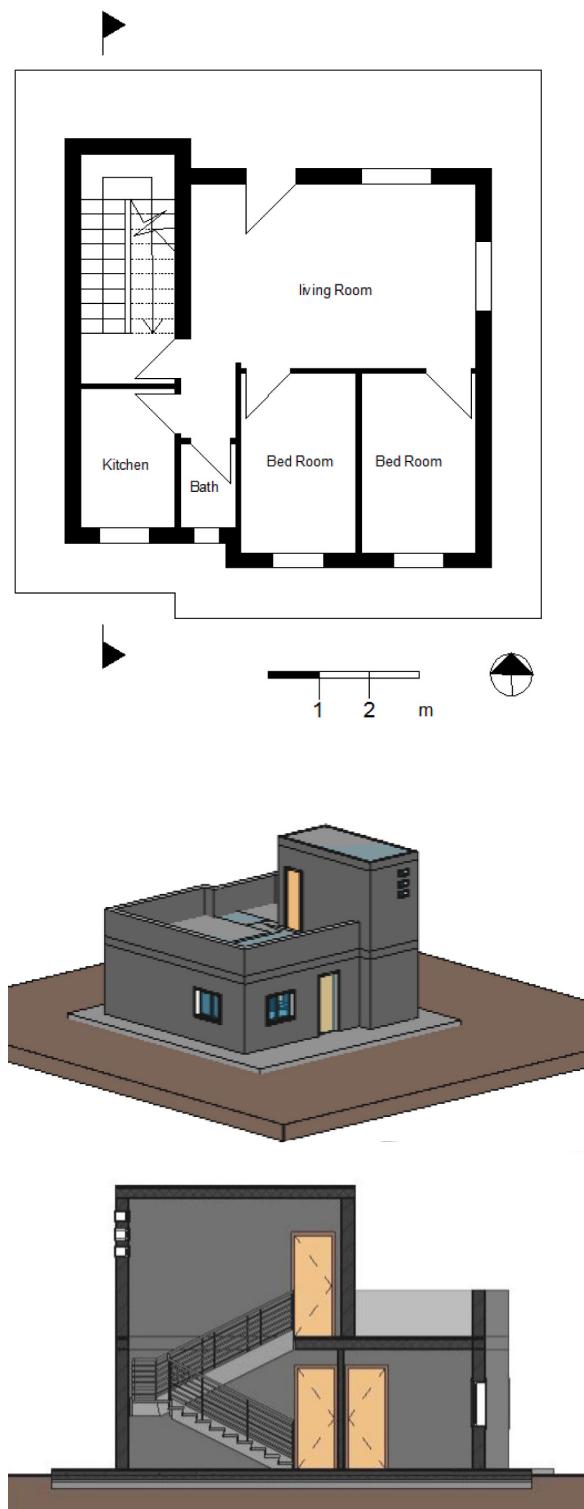
100 units from class B have 68 m<sup>2</sup> in total area. This research took class B as a case study to compare them with the vernacular dwelling because the same villagers were immersed from their vernacular dwellings and resettled in this class (HUDC, 2018).

The class B dwellings have one floor that includes one living room, two bedrooms, kitchen, bathroom and one staircase. (Figure 10).

The analysis of this dwelling type is clarified in Table 5, while the materials details and their thermal features are represented in Table 6. The research assumed the type of windows and doors similar with that used in Tables 2 and 4.

### Building simulation

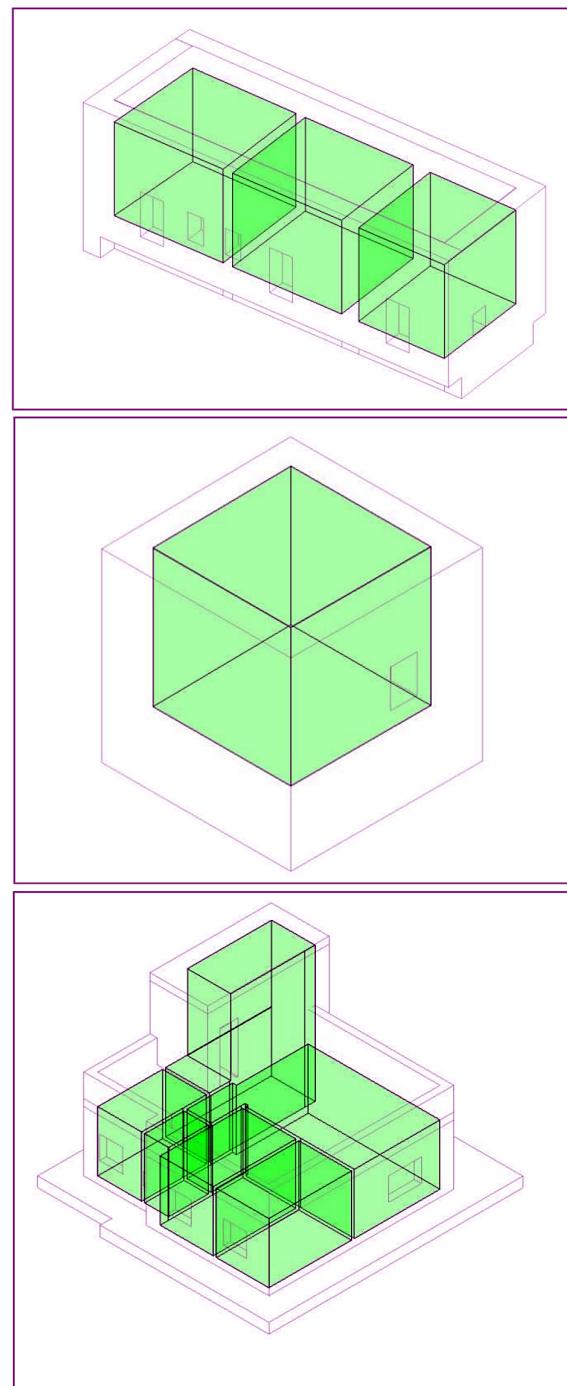
Autodesk Revit software was used to simulate the building typology, volume and envelope including construction materials and thickness of every layer as well as the impact of these variables on the thermal performance inside spaces. This software analyzed these spaces in a building model from each type of dwellings and compared them to calculate their energy consumption (Figure 11). The simulation assumed 70% for the absorbance of each envelope layer and 87% for the emittance. It assumed that the infiltration class in each dwelling



**Figure 10.** A present day dwelling. (A). Plan layout, (B). 3D modeling view and (C). Cross-section

is tight. The main HVAC parameters handled in this study were referenced to the ASHRAE standards.

The internal loads, the spaces appliances, the number of occupants (six persons) and the space occupancy schedules were considered as a constant in all spaces for each dwelling.



**Figure 11.** The internal thermal spaces analyzed by Revit software

## RESULTS

The results show that the contemporary dwelling has the highest peak heating load with an amount of 9,571 (Watt), which is 50% higher than the triple-space vernacular dwelling even though they have the same area of inside spaces, while the peak heating load of the single-space dwelling is 2,109 (Watt), see Figure 12.

**Table 5.** Dimensional analysis of the present-day dwelling units in the study (HUDC, 2018).

Type	spaces	Area of spaces( m <sup>2</sup> )	Height (m)	Openings position- Size ratio
Present- day dwelling	Living room	21	2.66	N: 6% E: 9%
	Bed room	8.28		S: 9.8%
	Bed room	8.28		S: 9.8%
	Bath	1.87		S: 5.4%
	Kitchen	5.31		S: 11.5%
	lobby	1.5		
	Staircase	8.74	5.62	

**Table 6.** The material's thermal properties used in present-day dwelling (HUDC, 2018).

Type	Materials	Thickness (cm)	Conductivity (W/m °C/m)	Specific heat (Kcal/kg °C)	Density (kg/m <sup>3</sup> )	U value (W/m °C)
External wall	Cement plaster	2.5	1.3	0.28	2000	2.9535
	Hollow concrete block	25	0.833	0.25	1300	
	Cement plaster	2.5	1.3	0.28	2000	
Internal wall	Cement plaster	1.5	1.3	0.28	2000	6.987
	Hollow concrete block	10	0.833	0.25	1300	
	Cement plaster	1.5	1.3	0.28	2000	
Roof	Cement mortar	2.5	0.93	0.29	1800	4.225
	concrete	3	1.7	0.24	2300	
	Asphalt-insulation	2	1.2	0.32	2300	
	Reinforced Concrete	20	1.28	0.26	2100	
	Cement plaster	2.5	1.3	0.28	2000	
Ground floor	Earth	50	1.4	0.22	1300	2.0304
	Basecoarse stone	15	1.5	0.23	2000	
	Asphalt-insulation	5	1.2	0.32	2300	
	Reinforced Concrete	10	1.28	0.26	2100	
	Sand	9	0.4	0.24	1700	
	Cement mortar	2.5	0.39	0.29	1800	
	Terrazzo tile	2.5	1.2	0.24	2000	

For cooling loads, it can be seen that the highest value is recorded at the contemporary dwelling, compared with the vernacular dwelling.

Overall, the contemporary dwelling has got a highest amount of cooling air and capacity more than the vernacular dwelling.

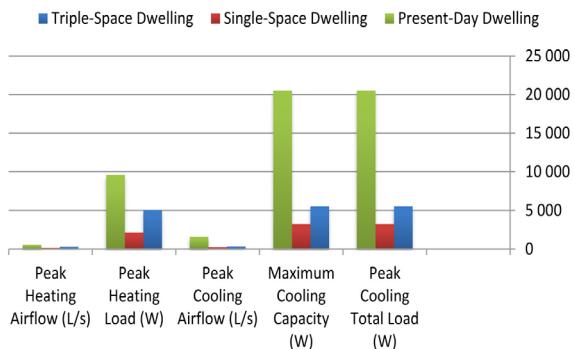
The results also show that the least heating load density per area was recorded at triple-space vernacular dwelling, while the heating load for the single-space dwelling is higher than the triple-space. The highest heating load density per area was recorded at the contemporary dwelling.

While comparing the cooling load per square meter, it is clear that there has been a significant difference between the present-day dwelling requirement and the vernacular dwelling. The cooling load of the present-day dwelling is three times

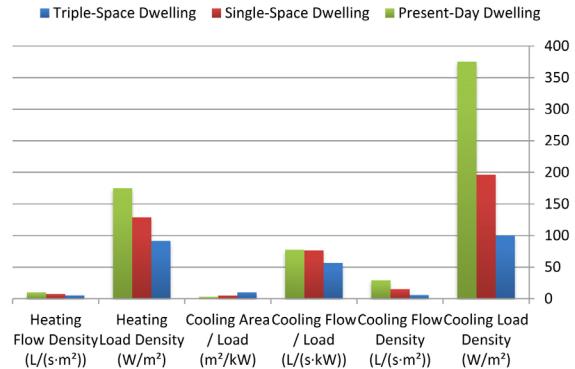
higher than that of the triple-space vernacular dwelling. However, the cooling load of the single space vernacular dwelling is double of the cooling load per area than that of the triple-space dwelling (Figures 13 and 14)

The monthly fuel and electricity consumption for all types of dwelling was also investigated. The results show the present-day dwelling consumes more fuel and electricity than the vernacular dwellings (Figure 14).

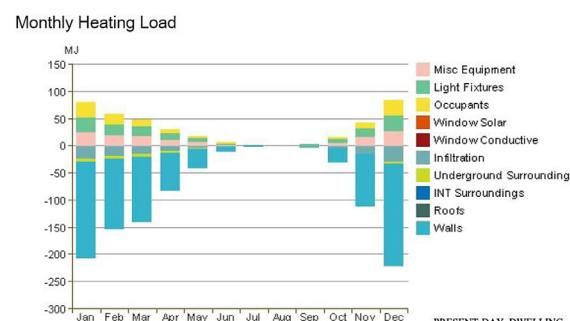
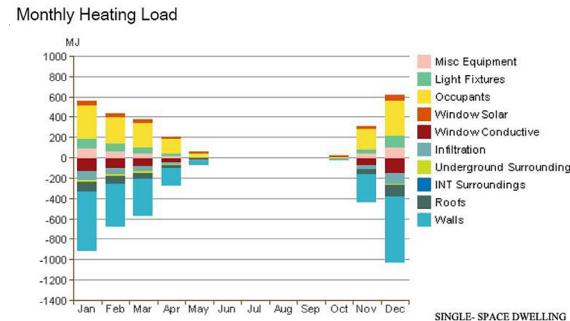
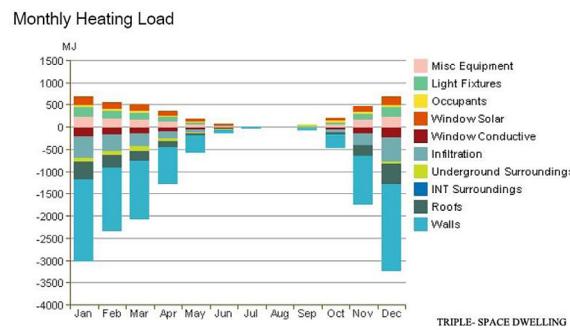
Detailed inspection for the dwelling architectural parameters was conducted as well. The heating loads were mainly attributed walls. Most of the heat loss was through walls because the temperature in winter goes to very low degrees and the u-value for the used walls in the new dwelling units is not according to the standards (Figure 15).



**Figure 12.** Peak heating and cooling load for all types of dwellings

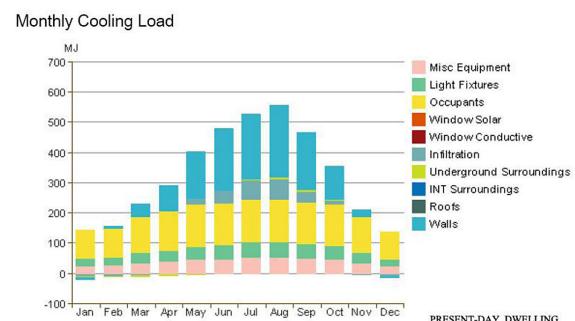
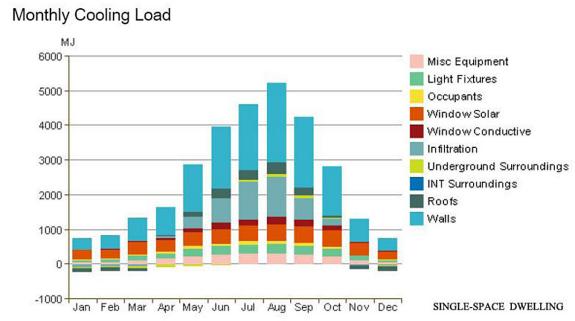
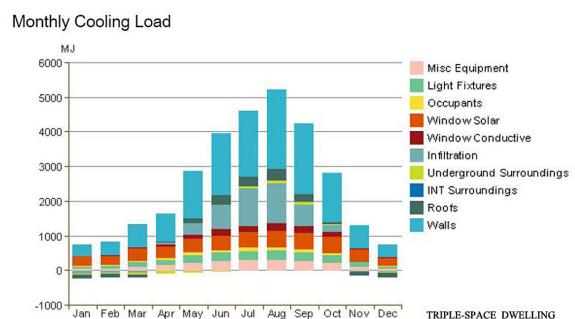


**Figure 13.** Heating and cooling load for all types of dwellings



**Figure 14.** Monthly heating load for specific parameters for all types of dwellings

For cooling loads, also the walls carry most of the loads for many reasons; first, the area of the walls is much larger than that of any building elements, secondly, the u-value of the walls in the new dwellings does not meet the code requirements (Figure 15). However, in the



**Figure 15.** Monthly cooling load for specific parameters for all types of dwellings

vernacular dwellings the conditions are different; the walls are made from clay and natural stone which makes the heat loss coefficient very low and eventually leads to minimizing the heating and cooling loads.

## CONCLUSIONS3

The study investigates and compares the contemporary dwelling units with the vernacular units. It is apparent that the new project in Umm Qais city does not meet the basic principles of sustainable design in terms of material choice and others. The old vernacular housing units proved to be much better than the modern ones. This should be very clear for the architectural designers to pay attention for this important issue in building design. Designers of the modern part of Umm Qais city have not considered the building orientation either. During the field survey; it was noticed that the four directions were not an important factor in the project and there was no treatment or solution related to any of the four directions.

The window size also was not taken into consideration in the project. It is noticed that the area of window is not proportional to the area of the room, which affects the amount of energy consumption for lighting.

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