Housing programmes in UAE: case study analysis based on regional sustainable standards and local microclimate

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Abstract
Cities like Dubai, Abu Dhabi, Al Ain, Sharjah, and Ajman are investing in housing programmes for the citizens of United Arab Emirates. The aim of this study was to analyse a housing district built under the housing programme in order to find the best scenario of the space distribution for reduction of the cooling load. This analysis was based on a typical unit plan and considered the local cultural factors (separated public zones for men and women), building orientation, and local climate (hot and arid).

The methodology consisted of the following process: (a) define the district, (b) conduct a site survey, (c) run the models with Revit as a simulation tool, and (d) analyse the result in order to define the best space distribution. The district selection was based on the available materials and access to the site for the survey. The energy simulations were accomplished with Revit, since it is a common tool (part of BIM) used by the architects in the region.

The results showed that changes in orientation of the unit zones (public and semi-private) can bring up to 5.2% of cooling load reduction in the full supply to the house. This saving was achieved by respecting the cultural factor (separation of the public zones from the private zones). Although more work needs to be done in investigating other input parameters, this result can improve housing energy efficiency by avoiding peak loads during the extreme summer temperatures.

1. Introduction
The United Arab Emirates (UAE) has undergone significant economic and urbanisation growth in the last four decades – a transformation that has raised concerns about its impact on the environment. The construction sector in the UAE accounts for 70% of energy consumption, mainly used in cooling (compared to the global average of 40%) [1]. The UAE government agencies (local and federal) recognize the energy–carbon reduction challenge and have introduced a sustainable development approach toward this goal, primarily through enforcement of building regulations that aim at increasing building energy efficiency.

The residential building sector forms the dominant part of the construction industry and accounts for the largest energy usage in the UAE [2]. Governmental intervention in the housing sector coincided with the discovery of oil during 1960’s. The high revenues generated therefrom enabled the government to act as the main housing provider for its citizens at both federal and local levels [3]. The majority of these
housing programmes are in the form of detached houses – the most demanding type of residence in terms of cooling, especially under the local extreme hot climate.

Housing has experienced major developments in terms of typology and size over the last few decades. As a response to the local families evolving requirements, the size of houses in such governmental programmes has increased from about 100m$^2$ in 1960’s to about 400 m$^2$ [4]. A large segment of the relevant research literature has extensively examined green building design and energy efficiency in a variety of climates [5]. However, few studies have addressed the UAE context and its local housing typology, construction methods and building envelope. In this context, Friess et al. [6] identified 30% potential energy savings in Dubai villas through appropriate external wall insulation strategies, including control of thermal bridging. Radhi [7], in his case study of the residential sector of Al Ain City, found that thermal insulation and thermal mass were important parameters to address in coping with global warming. He also found that window area and appropriate glazing systems are beneficial for and sensitive to climate change.

An existing residential unit in Al Ain City was examined by Tabet Aoul et al. [8] to identify energy upgrade opportunities and prioritise retrofitting solutions. Building orientation was found to be a critical factor that influences the energy needs of the structure. Several studies have investigated the impact of a building’s orientation and claim potential energy savings of 20–36% [9–11]. In this study, the impact of passive design parameters such as internal zone orientation and opening dimensions on cooling demand was theoretically investigated.

2. Methodology
The results of this study can serve as a valuable contribution to improving both the design and application of the housing program administered by local authorities in the UAE. The Air Conditioning usage reduction will contribute to decreasing overall energy consumption and improving the sustainability of such programs. The methodology is based on the standard process of analyzing a housing district.

2.1. Building Selection Process

2.1.1. District selection

![Figure 1: A. Town Location, B. District Location](image)

The area selected for analysis is part of a town called Al Shawayb. The town is located near the border with Oman; the closest city is Al Ain. The administrative area falls under the construction rules of Abu Dhabi. The housing compound is designated to the Emirati citizens as part of a national programme. There are 168 units in the district. The construction process was divided into three phases based on the location of the units. The district selection was based on the site information obtained during this study. Similar compounds are located in the cities of AL Ain, Abu Dhabi, Dubai, Ajman, and others.
2.1.2. Cultural factor as an input parameter

The focus of this study were the housing units designated for the Emirati citizens. The architecture of the complex, organisation of the internal zones, and use of construction materials are all related to the local culture. In other regions around the world, for example, the public zones usually merge with the semi-private zones (living area with the kitchen and dining zones, etc.). In this case study, the public zones are strictly separated one from another. Men have a separate sitting area from that of the women. These specific areas have separate entrances and different occupancy schedules. Therefore, any changes in the plan, based on the local culture of separating women from men, impacts the total cooling load of the full unit. The public zone is comprised of the male majles (men’s sitting area) and the female majles (ladies’ sitting area). These zones are separated by the use of internal walls. The majles are used for social gatherings – generally in the evenings, on the weekends or on festive days. The dining hall is also separated but can be accessed from both majles at different times. The kitchen is typically used to prepare the food, not to dine in. The family/living area is a semi-private zone accessible from the main entrance and the ladies’ majles. The second floor is mainly used as a private zone. Figure 2 shows a typical plan of a house constructed as part of this Emirati housing programme. The floor plan is repeated in the full compound considered in this study. The distribution of the zones is very similar to private homes in the UAE. Referring to the plan, the main factor that determines the location of the public zone is the main entrance. In this study, the two key factors considered in the redistribution of the zones were: (a) the north orientation and (b) the main entrance [12].

2.2. Site Survey

2.2.1. Survey of the building materials, building methodology

The site observation (survey) helped to better understand the building process, the applied materials, and the location of each unit. As can be seen from Figure 3, the units are repeated (mirrored in order to adapt to the entrance of each site). The north orientation is not considered in most of the cases. In almost half of the units in which the entrance faces south, southeast or southwest, the public zones are also oriented in the given direction. Since these zones have a high number of occupants, orienting them in a direction that is more protected from the sun could reduce the cooling load. The building materials are mainly concrete structures, with flat roof slabs, concrete blocks for the walls with internal insulation, wooden doors and double-glazed windows. In the energy models, the U values are based on the local building standards.

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**Figure 2**: Base Case House Plan, ground floor and first floor
2.3. Energy Simulations

2.3.1. Model Building Process in Revit. Run the simulations with several scenarios of the zone, orientation etc. Revit Model Description

The Revit energy analysis tool was used to evaluate the potential annual savings in cooling load for different virtual scenarios of the case study. This software program is easily accessible to building design professionals. It has a large database referring to weather files, structural materials, etc. [13,14]. In this study, 16 models were used, as presented in Table 1. The zone orientation was input as a main parameter, following the cultural factor. The U values were drawn from the literature and the site survey and were based on the local standards (roof 0.3183W/(m²K), exterior walls 0.5416, floors 0.7892, windows 1.6743, doors 2.1944). The house initial zones associated with the Revit zones were, primarily: Men’s Majles, Ladies Majles: Lounge/Recreation; Dining: Dining Area-Family Dining; Family Living/Hall-Dining Area- Lounge/Leisure Dining, Guest bedroom- Dormitory Bedroom, Kitchen- Food Preparation. In Figure 4, point (a), the different zones considered for this study are shown in green colour. The blue colour stands for selection of the second bedroom.

Table 1: Matrix table of the zone/window orientation

| CASE A1 | CASE A2 | CASE A3 | CASE A4 | CASE B1 | CASE B2 | CASE B3 | CASE B4 |
|---------|---------|---------|---------|---------|---------|---------|---------|
| MAN MAJLES (MM) | NW | na | Na | na | S | S | na | na |
| LADIES MAJLES (LM) | NW | NE | NE | NE | S | E | na | na |
| DINNING HALL (D) | NE | NW | NW | NW | E | E | na | na |
| GUEST BEDROOM (GB) | S | na | Na | na | NW | S | na | na |
| KITCHEN (K) | NE | na | Na | na | E | NW | na | na |
| WINDOW ORIENTATION 1 | na | na | NW to NE | NW to NE | na | na | SE to E | SE to E |
| WINDOW ORIENTATION 2 | na | na | NE to NW | NE to NW | na | na | SE to SW | SE to SW |
| WINDOW ORIENTATION 3 | na | na | SE to SW | SE to SW | na | na | na | na |
| WINDOW AREA REDUCTION 1 | na | na | Na | W1 | na | na | na | W1 |
| WINDOW AREA REDUCTION 2 | na | na | Na | W2 | na | na | na | W2 |
| WINDOW AREA REDUCTION 3 | na | na | Na | W3 | na | na | na | na |
2.3.2. Revit (BIM) opportunities/limitations

Revit is a software that falls under BIM (Building Information Modelling). Sustainable design approach calls for an understanding of building energy performance which, in turn, requires computer-based simulation software for rigorous building analysis. BIM software offers great opportunities for buildings, in that it allows coordinated and collaborated information about the building project to facilitate energy analysis early in the process [15][16]. The energy simulations in this study were accomplished with the 2017 version. Once the zones were defined as per the selected matrix, the simulation time was quite short (minutes). This allowed flexibility in trying out various scenarios using the same house layout. However, a few models analysed using a later version could not be read in the older versions. Another difficulty during the simulations was the overlapping of zones; therefore, an error margin was noted in the results [17][18][19].

2.4. Evaluations of the results

Since the results refer to units in a town in the UAE, local cultural factors were a main input in the matrix selected for the cooling-load and energy-savings analyses. Therefore, the results had two main points of relevance: (a) the cooling-load change and (b) the cultural factor (also considered as an input variable).

2.4.1. Cooling load analysis

As per the cooling load results shown in Figure 5, the Case A baseline (with orientation and main entrance towards the north) was the case with the lowest cooling load, and therefore the optimal plan. In this case, the public zones are oriented to the north side. In the UAE climate the north orientation is the favorite one in terms of energy saving. In Case B, the B4 configuration showed the lowest cooling load consumption. In Cases C and D, C3 and D4 configurations had the lowest values. The results show that a change in the zone orientation (B, C and D) can bring up to 5.2% of cooling load reduction in the

![Figure 5: Revit Energy Simulations results: a) four cases of cooling load and b) comparative case](image-url)
full supply to the house. However, Case B3 had an unexpected result: the part 3 of the case studies had a different window orientation (Table 1). The expected result was less cooling load than for Case B2.

2.4.2. Regional cultural factor impact

This study shows that considering the local cultural elements during the design phase, in combination with the orientation of each zone, can bring a drastic reduction in the cooling load. Compared to other regions, in the Middle East, the public and semi-private/private zones are very well defined and separated. This adds more space to a typical single-family house, compared to those seen elsewhere. Considering this factor makes the design and execution process environmentally and economically, but also socially sustainable. The results refer to the Arabic culture in particular. The methodology followed in this study can be applied in similar cities around the Middle East such as Riyadh, Jeddah, Cairo, Muscat, and Doha.

3. Conclusions and Future Work

In conclusion, and as shown in Figure 5, we have demonstrated that orientation of the public zones of a house play an important role in the cooling load of the building. Referring to the local culture of having all the zones separated by interior partitions, addressing the building orientation during the design phase can bring considerable energy savings in the cooling load.

However, more detailed models are needed. The selection matrix can be more complex, explaining the difficulties in achieving social/economical/environmental sustainable neighbourhoods as part of the national housing programme. The aim of future work is to extend the analysis from a single unit to a district level by improving the microclimate thru different strategies.

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References

[1] Wyman O 2011 Policies for the future 2011 Assessment of Country Energy and Climate Policies World Energy Council Project Partner.
[2] Khondaker AN, Hasan MA, Rahman, SM, Malik K, Shafuillah M and Muhlydeen, MA, 2016. greenhouse gas emissions from energy sector in the United Arab Emirates—An overview. Renewable and Sustainable Energy Reviews, 59, pp 1317–1325.
[3] P. St Clair, “Low-energy Design in the UAE, Building design principles,” 2009.
[4] T. Tareq and I. A. Abuibama, “Window Thermal Performance Optimization in the Government Built mirati Family House-Abu Dhabi Emirate,” 2013.
[5] A. Friedman, Fundamentals of sustainable dwellings. Island Press, 2012.
[6] S. T. W. Alexander Friess a, K. Rakshshanb, T. A. Hendawic, “Wall insulation measures for residential villas in Dubai: A case study in energy efficiency.”
[7] H. Radhi, “Evaluating the potential impact of global warming on the UAE residential buildings – A contribution to reduce the CO2 emissions,” Build. Environ., vol. 44, no. 12, pp. 2451–2462, Dec. 2009.
[8] “The Existing Residential Building Stock in UAE: Energy efficiency and retrofitting opportunities,” 2018.
[9] T. Catalina, J. Virgone, and V. Iordache, “STUDY ON THE IMPACT OF THE BUILDING FORM ON THE ENERGY CONSUMPTION.”
[10] U. T. Aksoy and M. Inalli, “Impacts of some building passive design parameters on heating demand for a cold region,” Build. Environ., vol. 41, no. 12, pp. 1742–1754, Dec. 2006.
[11] L. Spanos, M. Simons, and K. L. Holmes, “Cost savings by application of passive solar heating,” Struct. Surv., vol. 23, no. 2, pp. 111–130, Apr. 2005.
[12] “Middle East Sustainable Cities.” [Online]. Available: http://www.carboun.com/sustainable-design/passive-cooling-responding-to-uae’s-soaring-electricity-demand/ Journal.
[13] K. Rakshshan and W. A. Friess, “Effectiveness and viability of residential building energy retrofits in Dubai,” J. Build. Eng., vol. 13, pp. 116–126, Sep. 2017.
[14] “Create the Energy Model | Revit Products 2019 | Autodesk Knowledge Network.” [Online]. Available: https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2019/ENU/Revit-Analyze/files/GUID-A77EF18D-0EB8-47D3-A653-6379D9F1374A.htm. [Accessed: 30-May-2019].
[15] M. S. Morales Flores, “Building Performance evaluation using Autodesk Revit for optimising the energy consumption of an educational building on subtropical highland climate: A case of study in Quito,” 2016.
[16] F. H. Abanda and L. Byers, “An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling),” Energy, vol. 97, pp. 517–527, Feb. 2016.
[17] C. Wheatley, “Taking Analysis out of the Architects back room.”
[18] E. Guzmán Garcia and Z. Zhu, “Interoperability from building design to building energy modeling,” J. Build. Eng., vol. 1, pp. 33–41, Mar. 2015.
[19] L. Che, Z. Gao, and D. Chen, “Using building information modeling for measuring the efficiency of building energy performance,” Proc. Int. Conf. Comput. Civ. Build. Eng., pp. 165–170, 2010.