Journal of Water Sciences & Environment Technologies

Cit this: *JOWSET,* ***2020*** *(05), N°1, 535- 541*

Meta-innovation through project management to design Net Zero Energy Buildings TDART project as a case study

Jihane Abdessadak[1]*, Youssef Kharchouf[2], Sara Haffane[3], Mustapha OUARDOUZ[4], Mohammed Ahachad[5], Kamal Reklaoui[1].

[1] Research Laboratory "Engineering, innovation and management of industrial systems, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University- Morocco

[2] Faculty of Sciences and Techniques of Tangier, BP 416 – Tangier, Morocco

[3] Research laboratory, informatics, systems and telecommunications, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University- Morocco

[4] Research Team Leader Mathematical Modeling and Control, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University- Morocco

[5] Research Team "Thermal and Energy Transfers", Faculty of Sciences and Techniques of Tangier, Morocco

Current day technology is more than sufficient to build market competitive net-zero energy houses and buildings through the right legislation and policies. While most current households consume significant amounts of energy, they are the result of human heritage and collective knowledge concerning domestic life and family organization.
Which is why ignoring current and old home design and construction strategies would be a missed opportunity; even for radically different and novel approaches.
Named after the Amazigh word for "home", TDART aims to integrate local design strategies with modern technology to build the next generation of energy-efficient homes.
"Modern technology" referring not only to modern solutions and systems but to novel approaches inspired by scientific literature concerning construction, architecture, HVAC, etc.

Received: 20 October 2020
Accepted: 01 November 2020
Available online: 11 February 2021

Keywords:
Innovation
TDART project
Energy conservation
Architecture

Introduction

In any project that brings together different backgrounds, disciplines and personalities, making it all run smoothely will be a challenge, as is the case for TDART. Our ultimate goal remains to expose our members to the thick of industry and sustainable construction.
This experience will sharpen their skills and provide them with experience and a variety of tools that they can use in the future in order to further develop and contribute to their own fields long term, all while building an innovative net-zero energy house on the immediate term. But achieving this in a competitive context requires what we may call "meta-innovation".

On one hand, Innovation illustrates the meeting between two radically different worlds. The first is creativity, imagination, new ideas and the second is rigor and project management. And by successfully marrying both, we come up with innovative products, of course, but also technically developed and presenting real opportunities in a qualified market.
To achieve this objective, the imperative step is to follow a formal method for an innovative project management and to use the innovation methods.
On the other hand, the particularity of an innovative project lies in the need to propose something modified and improved or totally new to a new or existing market. In this sense, different project structures and management methods have been proposed in recent years, all aiming to find "the one best way" to manage projects through a structured approach in different stages. To do this, we will work with the methods OSEO and ADITEC that perfectly meet many of our criteria including cost control, time and quality while keeping good team cohesion.

We will opt for a bioclimatic architectural design, which is the art and know-how to make the best conditions of a site and its environment, for a naturally most comfortable architecture for its users, taking into account the orientation, the good distribution of the rooms of the habitat and the compactness. To highlight the Moroccan identity which is characterized by its diversity, its colors, its multitudes influences that knew the country during the history and finds its roots in the arabo-muslim art, that each region is characterized by his own signature.
Our TDART project was inspired by the charm, calm, discretion and construction techniques often found in riads and kasbahs. These are known by an inner courtyard, often surrounded by a garden, which constitutes the heart as well as the penetration of natural lighting that can be intelligently integrated into our habitat, with an implementation of automated shading systems that helps to control the intensity of natural lighting, provide the necessary shade in the summer and allow sunlight to passively heat the house in winter, while ensuring a building with net zero energy consumption that can be adopted at Mediterranean climate of the northern region of Morocco.

Meta-innovation

Innovation, the action of creating new processes and strategies, its purpose didn’t change over the years, but with the rapid advance in sciences and technologies it becomes less effective, extremely complex and no longer enough to add values to the organization. However by applying a variety of procedures to analysis how innovation is interpreted, we obtain an understanding of what makes innovative systems valuable, or how it can be strengthened and become more flexible. For this reason we need meta-innovation stage.

Innovating the innovation processes in the age of digital transformation is a huge advantage, there are massive resources, materials and technologies to combine with collecting and processing needed data can give us the capability to invent new models that are more powerful, impactful and flexible with the rapid technological and economical changing. Moreover, concerning human resources, creating diverse networks with matching individual skills satisfies several needs.

Project based approach

Considering TDART first and foremost as a prime example of project based pedagogy, our model is split into three approaches: Project, Competition and Human based (See figure 1) [1].

The project based approach rests on the idea of putting the students in the thick of industry, real-world practices and challenges with deadlines, quality requirements and budget caps. This provides them with much needed experience that will help them be more effective in similar contexts in the future.
The competition approach serves mainly to provide constant motivation to the team members. Working in a competitive context makes the students work harder to understand their abilities and learn how to collaborate with one another to make up a cohesive unit that works towards achieving a common goal.
The Human based approach is about task assignment according to background and ability, conflict management and team-building. We aimed to provide an environment where healthy minority dissent can help improve creativity, prevent premature consensus and encourage the majority to consider issues from different perspectives as was suggested by Nemeth [2] in the 80s.

This requires the team to have a high level of reflexivity, which is, as defined by West [3], overtly reflecting upon the team’s objectives, strategies and processes and adapt them to current or anticipated circumstances. We also occasionally applied the original and easy to implement SYMLOG method as it was first proposed by Bales in Interaction Process Analysis [4] during meetings to try and steer conversations into a more positive and more functional path.

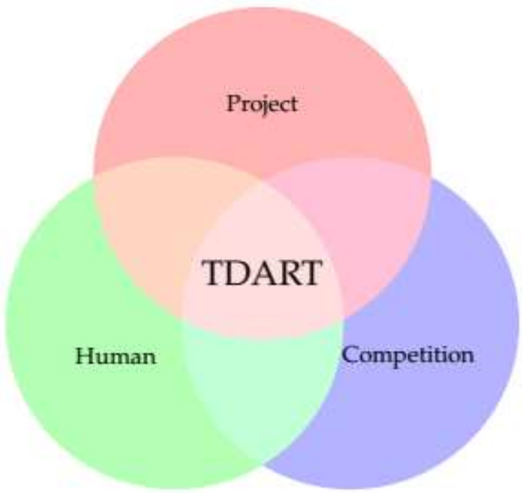

Figure 1: The three approaches to team management in TDART

The patio: a local inspiration with a new touch

Despite its association with Middle Eastern regions, courtyard housing is one of the oldest and most distinctive forms of domestic development, occurring in many regions of the world from Morocco to the Asian Far East across a time span of at least 5000 years [5]. The courtyard is considered an ideal environmental solution for conceiving a protected space within the hot climate of the Middle East [6]. While it does have some cultural and social significance from the fact that it provides a protected area with natural lighting and privacy at the same time, what's even more relevant to us is its impact on the house in terms of thermal comfort and airflow control.

The courtyard or "patio" is mostly shaded until late in the day even in low latitude regions. During the night, it loses heat by radiation to the sky [7] and provides natural cooling as the stratified cool air from convective flows in the courtyard seeps into the surrounding rooms. Many authors [8] & [9] conclude that a courtyard constitutes a free and passive cooling system for the house, with some reservations being shown by others [10], specifically for non-shaded courtyards where courtyard temperatures might turn out to be higher than ambient temperatures. TDART takes the best of both worlds and incorporates a retractable roof in the patio. This protects the courtyard from solar irradiation, keeping air temperature as low as possible when the roof is closed during the day and the sun is high, while also providing the option to open it to the sky in the mornings or later in the night to allow the walls and surface of the patio to radiate heat away towards the sky. It has been noted that a courtyard that includes a body of water (pond or pool) and that can be covered during the day provides remarkable cooling properties [11].

This is where the fountain comes in, apart from its aesthetic purpose, it salvages some of the benefits of a body of water and has a similar effect on the patio while being a much cheaper option than a pool.

In conclusion, TDART makes use of the patio's inherent cooling and ventilation properties and adds novel ideas such as a fountain and a retractable roof to improve it and mitigates some of the possible shortcomings of a simple courtyard. The patio-centered architecture is just another aspect of TDART's design strategies to reduce its carbon footprint.

Modular and sustainable from the ground up

One of the strategies of TDART to minimize our carbon footprint is to reduce the use of raw materials and cement as much as possible.

For the house foundation, we have opted to use helical or "screw" piles. We took this unorthodox route because of the potential gains of a sustainable cement-free foundation. In real world terms helical pile foundations are reusable, recyclable, tend to be faster to install and use less energy overall thanks to fewer required truck trips for raw material shipments or to transport excess soil away from the site. As far as we are aware this is one of the earliest African installations of helical piles for this specific type of application. Overall, helical piles are among the most environmentally friendly foundation systems [12]. And a consequence of this choice of foundation for the predominantly wooden structure of TDART that affects our entire construction phase is that water requirements are virtually eliminated.

Sustainable HVAC, insulation and lighting

There is a fair amount of literature [13], [14] & [15] on the usage of air conditioners in households with multiple units, the general conclusion being that it's very rare when a household uses all its air conditioners simultaneously. Air conditioning solutions have therefore conceptually trended from one air conditioning system for each zone to independent air conditioning for different zones under a single overarching system [16].

VRF (also known as VRV for Variable Refrigerant Volume) systems appeared originally in Japan in the 1980s and consist of a multi-split system of one outdoor unit and multiple indoor units. It is a ductless system similar to the familiar mini-split type air conditioners with an outdoor compressor unit feeding the expansion valves of the indoor evaporators using variable speed compressors. "Variable" flow stems from the fact that the system controls the amount of refrigerant flowing to each indoor evaporator. This property opens up different configurations with different evaporator capacities such as simultaneous heating and cooling and heat recovery from one zone to another [17]. It has been noted that sharing the outdoor units among multiple indoor units in a centralized multi-split type system is an effective optimization strategy [18] with predicted energy saving ratios of around 11-12% on a VRF system with original split-type air conditioners, depending on location. A few more factors that point to the VRF system as the optimal choice for TDART are the fact that it's a direct expansion DX system with lower maintenance costs than chilled water systems (no water treatment problems) and that it's inherently modular. Each module would be a quasi-independent refrigerant loop, although the modules would still be controlled by a common control system. Evidently, this fits nicely with the modular nature of the rest of TDART.

To supplement the VRF air conditioning we opted for a ventilation system with heat recovery. The system extracts air from the kitchens and bathrooms while simultaneously introducing fresh air from outdoors into the living room and bedrooms. During nominal operation the amount of air removed from indoors is similar to the amount introduced into the house by the system. During winter, heat from the rejected air is transferred to the incoming fresh air before it is led indoors, recovering considerable amounts of energy.

One of the first steps towards reducing the cooling/heating load of any building, regardless of the type of air conditioning used, is thermal insulation. An insulating envelope can significantly reduce the energy and the size of the required air conditioning system. It also helps retain acceptable thermal comfort conditions for longer. While commercial insulation materials like extruded polystyrene (XPS) have good sustainability characteristics, we opted to supplement ours with textile waste. There is a significant amount of textile waste that is discarded each year by the textile industry, and only a small percentage of it is recycled. Finding different applications for it is a straightforward solution. This particular application of textile waste as thermal insulation has been investigated before. Fabric waste was found to be an adequate alternative to EPS/XPS insulation by Briga-Sa et al. [19] and El Wazna et al. [20] found acrylic and wool based nonwoven waste to have excellent thermal insulation properties. This encouraged us to try nonwoven textile waste that contains a combination of PES-Acrylic-Cotton and bi-component fibers as an additional insulation layer on top of the XPS (See figure 2).

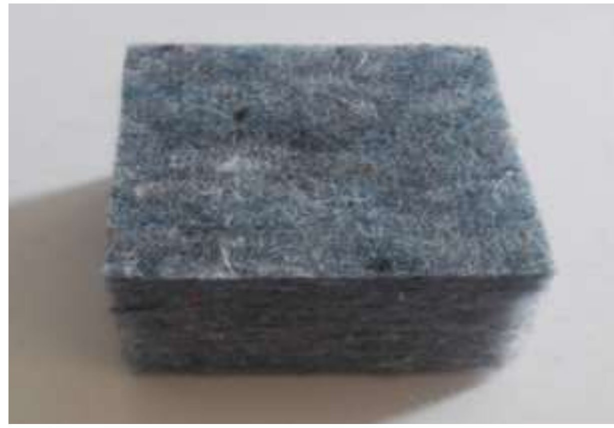

Figure 2: A sample of the nonwoven textile waste insulation

The exact effects and performance of this kind of insulation is difficult to measure due to lack of standardization of textile waste and ambiguity in its porosity and thermo-physical characteristics. Nevertheless, we are hopeful that this type of insulation can provide a more sustainable alternative to traditional commercial insulators in the future. Table 1 represents the physical properties and composition of the used textile waste insulation in the TDART house (See tab 1).

Tab 1: Physical properties and composition of the used textile waste insulation

Property	Value			
Composition	*PES:*	40%	*Acrylic:*	15%
	Cotton:	10%	*Bico:*	35%
Density ($kg\,m^{-2}$)	37			
Thermal conductivity ($W\,m^{-1}\,K^{-1}$)	~ 0.037			
Thermal resistance[18] ($m^2\,K\,W^{-1}$)	~ 1.351			

A third aspect of our system is the inclusion of a simple and affordable house automation system that provides adequate energy savings within our budget. It is a simple light dimming system that provides the option to reduce consumption when natural lighting is available or to set the mood when dim lights are simply desired by the inhabitants.
Controlling the shutters and the retractable roof is also possible with this system.

TDART team would opt for a bioclimatic architectural design that uses many, simple and feasible, building strategies and principles to heat, cool and ventilate the building.
Bioclimatic habitat takes advantage of the climate to bring its occupants closer to comfort conditions; bioclimatic architecture puts the occupant at the center of its considerations to achieve all of this, we will focus on the following instructions:

Implantation

The judicious implementation of TDART house is an important phase in the architectural design. It determines the lighting, the solar gains, the wastage, the possibilities of aeration, but also the qualities of the habitat: Communications, views, neighborhood reports.

Orientation

In order to profit from passive solar gain, the TDART building will be oriented towards the South because the sun is available there all year round. The layout of the rooms in our building will be as shown in figure 3.

Figure 3: Room layout in TDART house

Finally TDART includes multifunctional sealing membranes which double as a high albedo "cool roof" (Figure 4 represents the different temperatures with and without a cool roof).

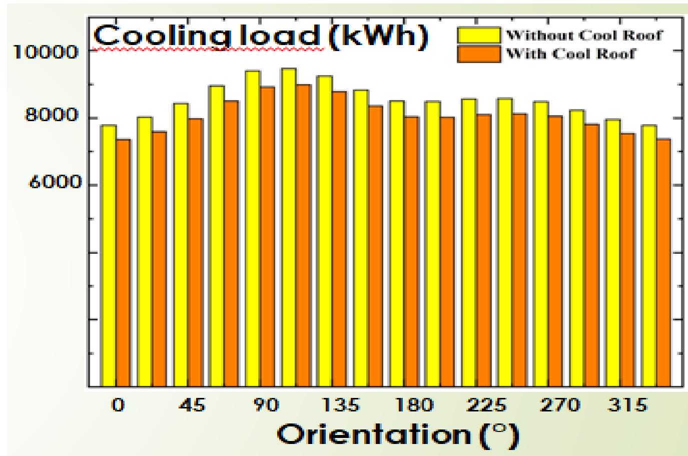

Figure 4: Temperatures

Previous literature suggests significant air-conditioning energy savings can be achieved in high temperatures which are prevalent in the African climate [21] & [22] especially in urban heat island environments. In a 1999 study, researchers extrapolated simulation data to the US and estimated that white roofing can potentially save up to 10 TWh per year. A more recent study [23] of a typicaloffice building in Rome, Italy found a decrease of 34% in energy requirements for cooling. In terms of environmental impact, cool roofs have been shown to be three times more effective than green roofs at cooling the globe for climate change mitigation [24], making this a very attractive solution for TDART.

Natural lighting

Our natural lighting strategy aims to better capture and penetrate natural light, then better distribute and focus it. We will also take care to control the light to avoid visual discomfort (See figure 5).

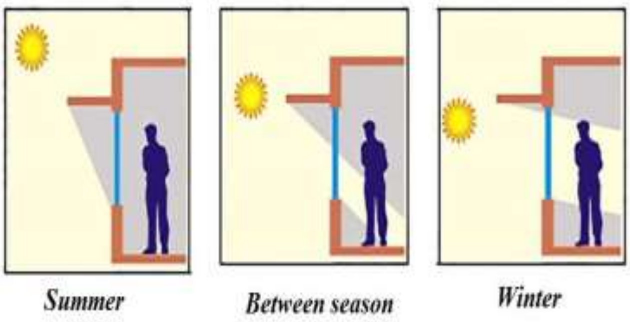

Figure 5: Natural lighting scenarios in TDART building

Compactness

The shape of our building is an interesting thermal evaluation criterion because it indicates the degree of exposure of the building to the ambient climatic conditions. In our TDART project, we will try to minimize the area of loss by maximizing the envelope, which translates into a low compactness.

Openings

Openings including windows in winter allow the penetration of solar energy which ensures energy saving and natural lighting. TDART opening represent 28% of the living space, 18% of which is on the south side. In addition to reduce heat loss and overheating due to solar radiation we opt for double glazing and smart solar protection.

Ventilation

In order to limit the rise in temperature in our building, an approach based on the establishment of air flows that evacuate internal heat gains and solar gains will be exploited.

Conclusion

The purpose of this work was mainly to present the innovations; such as the improvement of the building envelope and the heating, ventilation and air conditioning system, in order to obtain a better indoor thermal comfort; that we have implemented to design the TDART project house. The latter which participated in the international Solar Decathlon Africa competition held in 2019 in Morocco. Several measures were taken into account in this competition

The results of the competition will be detailed in our next article.

The practical strategies presented in this paper could be very useful for architectural designs to replicate the TDART house for implementation in a near-zero energy house in the African continent and the Mediterranean region.

References and notes

1. Abdessadak, J., Ouardouz, M., Mahdaoui, M., Elalaiji, R., Ahachad, M., & Reklaoui, K. (2019). Apprentissage par projet et autonomisation Etude de cas: Projet TDART UAE. *Revue Internationale d'Economie Numérique*, *1*(1), 26-34.
2. Nemeth, C. J. (1986). Differential contributions of majority and minority influence. *Psychological review*, *93*(1), 23.
3. West, M. (1996). *Reflexivity and work group effectiveness: A conceptual integration* (pp. 555-579). John Wiley & Sons, Ltd.
4. Bales, R. F. (1950). Interaction process analysis; a method for the study of small groups.
5. Edwards, B., Sibley, M., Land, P., & Hakmi, M. (Eds.). (2006). *Courtyard housing: past, present and future*. Taylor & Francis.
6. Radoine, H. (2017). *Architecture in context: Designing in the Middle East*. John Wiley & Sons.
7. Batty, W. J., Al-Hinai, H., & Probert, S. D. (1991). Natural-cooling techniques for residential buildings in hot climates. *Applied energy*, *39*(4), 301-337.
8. Scudo, G. (1988). Climatic design in the Arab courtyard house. *Environmental Design: Journal of the Islamic Environmental Design Research Centre*, *12*.
9. Fathy, H. (2014). Natural energy and vernacular architecture. *Natural Energy and Vernacular Architecture*, 28-32.
10. Etzion, Y. (1990). The Thermal Behaviour of Non-Shaded Closed Courtyards in Hot-Arid Zones [1]. *Architectural Science Review*, *33*(3), 79-83.
11. Al-Hemiddi, N. A., & Al-Saud, K. A. M. (2001). The effect of a ventilated interior courtyard on the thermal

performance of a house in a hot–arid region. *Renewable Energy*, *24*(3-4), 581-595.
12. Perko, H. A. (2009). *Helical piles: a practical guide to design and installation*. John Wiley & Sons.
13. Jian, Y. W., Li, Q. R., Bai, Z., & Kong, X. D. (2011). Study on influences of usage behavior of residential air handling unit on energy consumption in summer. *Building Science*, *27*(12), 16-20.
14. Ran, M., Liu, X., and Hu, S., Wu yang architecture college, huaqiao university; the monitoring investigation and related analysis on the air conditioning in summer for residential building at xiamen. *Building Energy & Environment*, 1, 2011
15. Li, X., Xie, D., Jiang, H., et al. Testing study on operating behavior and energy consumption of air conditioners in residential buildings in beijing. *HV&AC*, 2:15–20, 2014
16. Park, Y. C., Kim, Y. C., & Min, M. K. (2001). Performance analysis on a multi-type inverter air conditioner. *Energy Conversion and Management*, *42*(13), 1607-1621.
17. Goetzler, W. (2007). Variable refrigerant flow systems. *Ashrae Journal*, *49*(4), 24-31.
18. Li, Z., Wang, B., Li, X., Shi, W., Zhang, S., & Liu, Y. (2017). Simulation of recombined household multi-split variable refrigerant flow system with split-type air conditioners. *Applied Thermal Engineering*, *117*, 343-354.
19. Briga-Sa, A., Nascimento, D., Teixeira, N., Pinto, J., Caldeira, F., Varum, H., & Paiva, A. (2013). Textile waste as an alternative thermal insulation building material solution. *Construction and Building Materials*, *38*, 155-160.
20. El Wazna, M., El Fatihi, M., El Bouari, A., & Cherkaoui, O. (2017). Thermo physical characterization of sustainable insulation materials made from textile waste. *Journal of Building Engineering*, *12*, 196-201.
21. Akbari, H. (2003). Measured energy savings from the application of reflective roofs in two small non-residential buildings. *Energy*, *28*(9), 953-967.
22. Akbari, H., Konopacki, S., & Pomerantz, M. (1999). Cooling energy savings potential of reflective roofs for residential and commercial buildings in the United States. *Energy*, *24*(5), 391-407.
22. Pisello, A. L., Santamouris, M., & Cotana, F. (2013). Active cool roof effect: impact of cool roofs on cooling system efficiency. *Advances in building energy research*, *7*(2), 209-221.
23. Sproul, J., Wan, M. P., Mandel, B. H., & Rosenfeld, A. H. (2014). Economic comparison of white, green, and black flat roofs in the United States. *Energy and Buildings*, *71*, 20-27.