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SIMULATION BASED - EARLY DESIGN TOOL (SBED) FOR APARTMENT BUILDINGS

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Abstract. *Estimating the thermal performance of buildings using simulation programs during the design phase can help to move towards greener buildings in the future. However, thermal simulation is usually time consuming, expensive and needs expertise and detailed information to be conducted which is not always available. To overcome these challenges, there is a need for simplified tools and applications to help the designers to integrate energy simulation during the early design phase with minimum effort, time and expenses considering the local building materials, local construction techniques, typical building designs and the climatic conditions. This study presents simulation-based tool that accommodates the Palestinian context and that help the designers to make decisions at early design stages by guiding them toward energy efficient buildings. The tool was designed for the apartment buildings by defining the building prototype then conducting sensitivity analysis, then parametric simulation was performed to rapidly and flexibly assess thermal performance and energy consumption of different envelope design alternatives. Energy consumption in residential buildings can be minimized by 30% if designers define envelope related parameters at early design stage.*

1 INTRODUCTION

Energy consumption and building performance can be affected to a great extent by different parameters such as: climate, building construction techniques, building architectural features and inhabitants [1] [2] [3]. Climate as well as the climatic variations through the year impact the thermal performance of buildings and defines the amount of energy needed to reach the comfort levels [4]. Building construction in terms of building size [5], envelope U-values [6], thermal properties of construction materials and levels of infiltration [7] [8] [9] [10] determine the building performance of the building through dynamic interaction with the surrounding. In addition, households' habits, behaviour and way of using the space [11] as well as inhabitants age, number of family members and income have a great impact on the energy consumption and the thermal performance of the buildings. [12] [13] [14] have tested the influence of different parameters on the performance of building envelope and have found that such factors can be very critical and can affect the performance of the building envelope itself while also affecting the energy consumption and user's comfort. Quality indoor environments will have a positive effect on users' health and wellbeing as well as on their productivity and comfort [15].

Energy Consumption worldwide has shown great increase recently with an annual average of 1.8% to 2% between the years of 1984 to 2004 [2]. Buildings account for about 40% of the global energy consumption in which a great percentage of such energy is consumed so as to achieve thermal comfort in buildings [16]. The energy sector in Palestine faces many significant challenges due to the lack of primary energy resources and due to the fact that energy is usually imported from Israel which has resulted in financial and political problems [17] [18]. The Residential sector account for about 60% of the total energy consumed in Palestine [19]. Special attention is needed to minimize energy consumed in buildings and a special concentration is needed to point out the reasons behind such consumption. Rethinking and improving building envelopes can contribute to a more energy efficient buildings and to a higher comfort level.

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Careful selection of construction materials involved in envelope components (walls, roofs, windows, foundations, …etc.) is highly recommended since these materials can be combined carefully to achieve specific function such as thermal comfort, acoustic comfort, natural daylight harvesting and energy efficiency. Construction materials can be combined or arranged in different ways to introduce different types of building envelopes. In walls for instance, the materials can be arranged in different orders and with different thicknesses. Different insulation materials can be used. Insulation materials can be applied to the inner part or the outer part of the wall. Different envelope orientations should be treated differently. In many countries such as Palestine where there are no building regulations related to building envelope selection and consideration, common walls, roofs and floors are rarely insulated. Many factors are influencing the selection of construction materials. The most common factor is the availability of construction materials in the desired building context by means of available resources. Another issue is related to design considerations such as building type, social and cultural values as well as common construction practices. Moreover, existing codes and regulations followed such as seismic codes, firefighting codes as well as structural loads can be a major influencing factor as well. Cost, financial issues and maintenance considerations are also important.

The building envelope is the critical part (layer) that can control the quality of indoor environments. The indoor space energy demand is highly connected to the efficiency of the building envelope. 20 – 50% of heating and cooling demand is produced from the design and properties of the building envelope only [20] [21]. There are many different ways to improve the performance of building envelopes. Method one _which is the focal method in this study_ is by the use of high-performance building materials such as employing insulating materials, high quality glazing as well as good quality thermal aluminum to eliminate air leakage and heat gain and loss through building envelopes. The second method is by using advanced and sustainable building materials such as: phase change materials, unfired clay bricks, aerated concrete blocks, …etc [22] [23]. The third method is by using sustainable techniques in constructing building envelopes such as: the tromb wall, the ventilated double skin façade, wall based solar chimney, solar walls and integrated greenery walls [24]. Or a combination of these. All these methods have been studied and elaborated recently as a result of the recent increase interest in environmentally friendly and energy efficient buildings [25].

Heating energy needed due to envelope components is highly affected by the envelope component U Value. It can be calculated by multiplying envelope U values (walls, glass and roofs U values) with its area and with the difference in temperature between the desired indoor temperature and the average outdoor air temperature as per the equation $Q=UA\Delta t$ [26].

Parametric simulation is a kind of building simulation. Parametric is derived from the word parameter. It may be defined by measurable and quantifiable feature [27] [28][28][28][28][28][28][28][28](28)[28](Hudson 2010)[28][28][28][28][27][27] (Hudson, 2010). Such definitions have led to its methodology used throughout this paper where parametric simulation is treated as measurable factor that led to optimum solutions [28]. It helps in testing different design decisions. It can be very effective in predicting the best building design related performance. Parametric simulation can be an optimization strategy toward better building performance [29]. It can be a supporting decision making method that is very effective during design phases [30]. Parametric design is an approach to generate and explore a wide range of design alternatives [31]. It allows testing unlimited variables while evaluating and comparing what best suits the specific design condition. However, if done by a computational simulation engine, it might take a long time and effort which makes simplified tools highly recommended.

Parametric design is usually a presentation of a design with constant and variable parameters. The designer can manage to change the variable parameters to achieve different solutions to the problem associated with the designed parametric model. It is a method based on relationship thinking and testing the effect of such relationships on the designed model [29]. The parametric design process starts by defining the variable parameters that need to be tested, identifying the relationship between the different parameters, clearly identifying the design conditions in order to create variations and to test the results [32].

Parametric design method has unlimited advantages. It considers all relevant parameters that may affect the design. It leads to determining and choosing the best parameter while understanding its effect on the design. This study proposes a simulation-based tool to help designers test different envelope related parameters and their effect on building performance and on energy consumption through parametric simulation and sensitivity analysis. To be used for designing apartment buildings in the Mediterranean climate and for the common building technology used in Palestine.

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2 METHODOLOGY

2.1 Building Prototype

Residential buildings designs fails if it doesn't consider the occupants [33]. This is very true when observing residential buildings in Palestine. Socio cultural values are never ignored in this type of buildings. Visual privacy is highly needed. Large Window to Wall Ratios (WWR) or completely glazing facades are never found or accepted. Apartments' compositions in terms of accessibility as well as access to view need to be private.

Three apartment typologies have been taken as base case studies. The three typologies shown in figures 1, 2 and 3 were found to be representative models for residential buildings in the study context depending on the number of residential units per floor. Typology one as shown in figure 1 represents two residential units per floor building. The average area of one apartment is 150 m² with a net heated and cooled area of 40m2 representing the common living space area (which is the common practice in Palestine). The second typology as shown in figure 2 represents three residential units per floor building. The average area of each apartment is 155m² with a net heated and cooled area of 40m² also representing the living space zone. The third typology represents four residential units per floor building. All three typologies are of five story building blocks based on the Palestinian Local Buildings Regulations. All typologies share the same construction techniques:

- Wall Systems: Stone walls are widely spread in the Palestinian cities and in some villages. It is very common in the construction of residential buildings. Stone thickness varies from 3 – 5cm [34]. However, since the majority of these buildings are constructed to be sold by investors to homeowners, stone thickness was minimized to 3cm thick stone to save money in construction. The external walls are constructed from 3 cm stone cladding material, 25 cm concrete layer as shown in figure 5.

- Roof Systems: reinforced concrete slabs are found to be widely used for roofs in residential buildings with water treatment membrane on top [34]. Inclined concrete layer covered with asphalt layer are the most common water treatment membrane. Concrete slabs are rarely insulated. See figure 7.

- Floor Systems: floors consist of 26cm reinforced concrete slabs, 15cm sand and cement mortar to separate the concrete slab from the porcelain tile (the finish material) [34] as shown in figure 6. Sand thickness varies depending on the amount needed to cover all electrical and mechanical pipes installations.

The energy losses in buildings and specifically in the residential sector reaches 25% resulting from the external walls only (The World Bank Group, 2016).

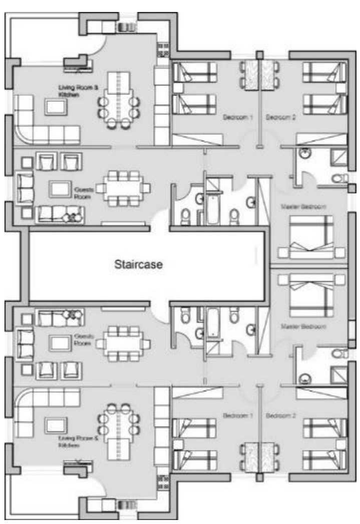

Figure 1. Building prototype 1

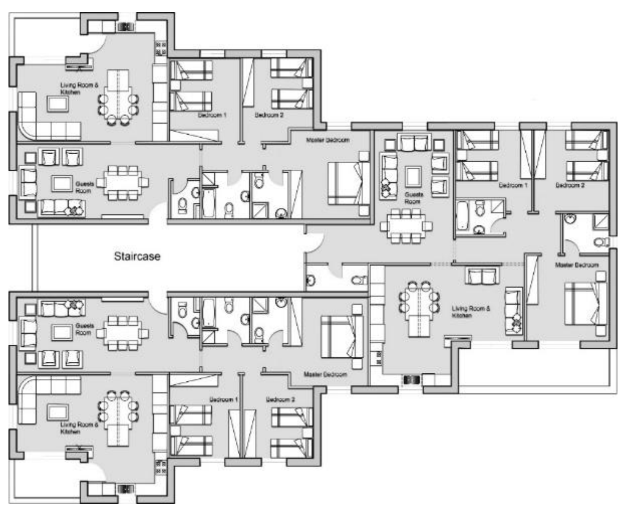

Figure 2. Building prototype 2

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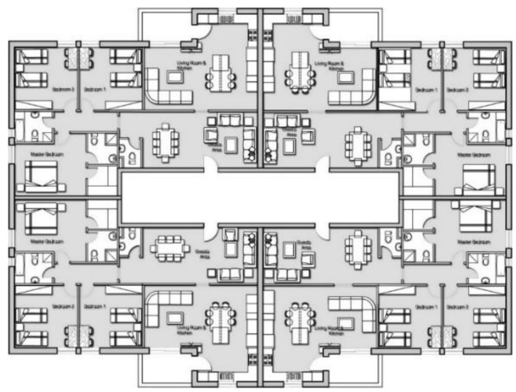

Figure 3. Building prototype 3

2.2 Sensitivity Analysis

For the purpose of this study and for the need to determine the main variables that affect thermal performance and energy consumption. Different simulations were conducted to perform sensitivity analysis by changing only one variable at a time while keeping others constant_ was used to check the effect of building layout (number of residential units per floor), orientation, floor level, types of stones available in the study context, insulation, glass type and topography on the previously mentioned sustainable factors (building performance and energy consumption). This has helped and led to classifying parameters as shown in table 1 depending on their effect on energy consumption. Those classified categories are the design parameters (variables), constant parameters and confounding variables. Design parameters are the elements that are allowed to vary during the assessment process while constant parameters related to common design practices. Confounding variables are factors that can't be controlled by the user but may still influence the building performance such as occupancy, lighting, buildings schedule and residential appliances…etc.

Figure 4 shows a simplified scheme of the overall cases that will be part of the developed tool. Part of these cases will be defined as base cases which means they has base case envelope (most common envelope) as shown in figure 5, 6 & 7. The tool will be designed to give the user the ability to compare base cases with cases that involves the use of newly defined parameters to check their influence on energy consumption as well as on building performance. Moreover, the tool will provide the user with the potential energy savings and the approximate annual cost compared to the base case scenario. All cases were simulated using Design Builder simulation software and in a fixed weather data representing the climate of Jerusalem.

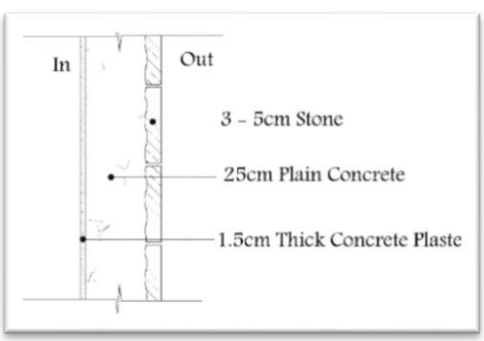

Figure 5. Vertical section in base case wall

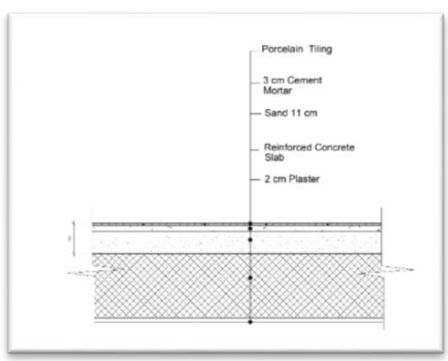

Figure 6. Horizontal section in base case floor

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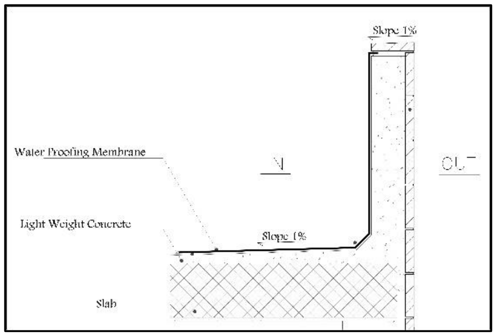

Figure 7. Horizontal section in base case roof

Design variables (Input Parameters)	Constant Parameters	Confounding Variables
- Building layout (Residential units per floor) - Orientation - Floor Level - Insulation thickness - Glazing type and color - Aluminum type (normal aluminum or thermal break aluminum) - Urban context - Topography	- Wall configuration as shown in figure 5 - Window to floor ratio - Insulation Type	- Occupancy - Lighting - Appliances

Table 1: Categorizing Parameters

3. IMPACT OF ENVELOPE DESIGN ON BUILDING PERFORMANCE AND ON ENERGY CONSUMPTION

Indoor air temperature is used for measuring building performance. A comfortable indoor environment has been what humans always try to achieve in their buildings. A comfortable environment and a good building performance can be achieved by the use of proper envelope materials which are usually coupled with heating and cooling systems. Building thermal performance is an important step in the design process but is ignored in many cases. This is due to the cost, time consumed, lack of expertise and lack of needed data to perform such analysis. Hence, simplified simulation tools can give an idea of the building performance by testing the effect of different envelope configurations on building performance. It is very important to evaluate the performance of different envelope configurations and so to properly select the best combination that provides better indoor air temperatures and minimum energy consumption.

3.1 Conducting Parametric Simulation

Usually in early design phases, designers test different concepts and alternatives to reach final design. Parametric design is highly needed to face challenges and to come up with the best design alternative. The designer needs to run through different parametric simulations to figure out the best design that provides best indoor environment performance as well as minimum energy consumption. This paper presents a platform where the designer can evaluate different envelope related parameters and test their effect on thermal performance and energy consumption in a simplified and fast method. The process depends on algorithm structure. The algorithm structure for this research is shown in figure 8 and has been used throughout this study to assess both building performance as well as energy consumption. Table 2 summarize the parameters being adjusted throughout the parametric design process.

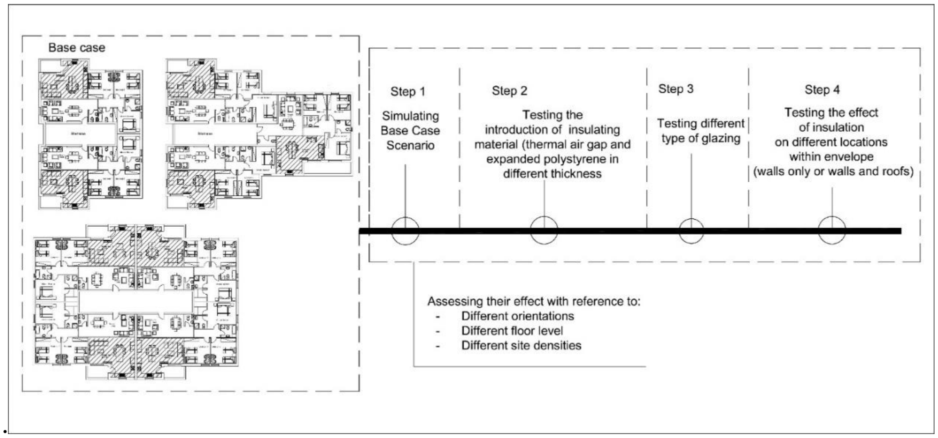

Figure 8. Algorithm structure

Parameters	Attributes	No. of Values
Insulation thickness	Variety of thickness	3
Insulation material location	Variety of location within envelope	2
Glazing materials	Variety of glazing properties	4
Aluminum frames	Variety of two types	2
Building design	Variety of number of apartments per floor	3
Building orientation	Variety of orientations	8
Floor level	Variety of levels	4
Site densities and topography	Varieties of urban densities combined with topography	4
Total number of variables parameters		**22**

Table 2: Building and design parameters adjusted during the parametric design process

3.1.1 Parametric Design Algorithm

Based on the proposed algorithm structure, different envelope configurations can be tested. They will be tested against a fixed orientation, a fixed floor level and an estimated urban context scenario. The base case envelope will follow the following series of parametric commands under certain variables and precisely defined constants as per the following:

1. Simulating the base case scenario (a)
2. Simulating the effect of adding thermal air gap insulation as well as block 7cm to base case wall (b)
2. Replacing thermal air gap by an insulating material (Expanded Polystyrene) (c)
3. Checking the effect of different insulation thicknesses on building performance (d)
4. Applying different glazing properties to the different insulation thicknesses to check their effect on buildings performance (e)
5. Adding Insulating layer to roofs (f)
6. Using thermal break aluminium with the best envelope configuration found (g)

For accurate results, the different parametric commands were applied to the whole building despite the fact that this study focus on the performance of the living space specifically.

3.2 Evaluation Criteria

The evaluation followed relied on a comparison approach between base case and the proposed envelope commands. The command that gives better performance and less energy consumption will be favoured and recommended. Both building performance and energy consumption are of direct relation and that's the reason why they're evaluated within the same evaluation criteria. The difference in temperature between the indoor air temperature

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and human comfort temperature directly affect the amount of energy needed in source of heating and cooling to reach the comfort temperature. The average comfort temperature presented in the proposed tool as well as the comfort range is calculated based on the adaptive comfort Standard presented in ASHREA 55-2010 which use the following equation to calculate the comfort temperature: $T_{comfort} = 17.8 + 0.31 * T_{outdoor}$ [35].

3.3 Parametric Simulation Results

As shown in figure 10, 4720 simulation were conducted to develop the tool. Parametric simulation results provide the user with complete set of options and alternatives so as to decide which option might best fit the desired objective which in some cases might not be the case that produced the minimum energy consumption or the optimum solution. The tool gives the user the ability to compare results and choose what suits best his or her design and client needs and budget.

3.4 Validation of Parametric Simulation Results

Calculation of heating and cooling demands to estimate total energy consumption is usually affected by unlimited factors. The building activity, the number of residents and their age [36], residents activity and behavior as well as the total occupancy hours [37] [38], individual metabolic rate [39], envelope insulation [32], glazing type, window to wall ratio, building orientation etc.… Computer simulation models are programmed based on thermodynamic principles and have proven to be very important in building simulation and in testing building performance [37]. However, their use requires a set of assumptions. For the purpose of this study, it was assumed that HVAC system is used in the living space with set point winter temperature equals to 21°C and set point summer temperature equals to 25°C with time frame 12 hours per day. Occupancy density as well as activity factor and clothing schedule definitions were set as fixed values in the simulation program. Any changes in the previously mentioned factors, in simulation program set point temperature will affect heating and cooling loads and so getting actual measurements from existing buildings in the study context was not considered. Setting the simulation program to accommodate all common practical applications can't be ecological that's why the intent of this tool is to give percentages of saving in comparison with building performance while taking all the pre-defined parameters into account.

A Rule of Thumb Method developed for Heating and cooling Loads calculations especially for Palestine [40] was used as the main method to validate simulation results. A rule of thumb as defined by the authors is an easy and simplified method to calculate approximate loads while preserving high level of accuracy.

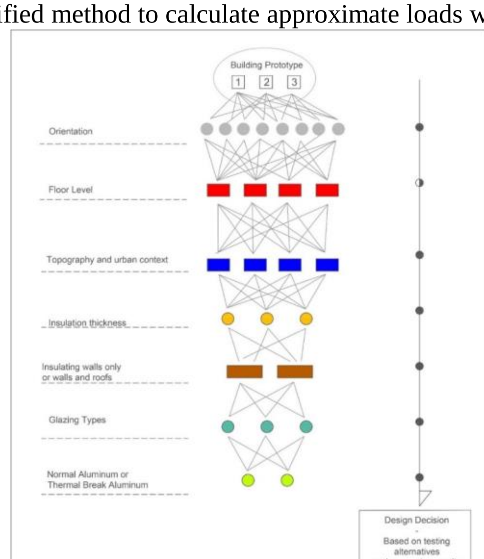

Figure 9. Parametric testing process to formulate results

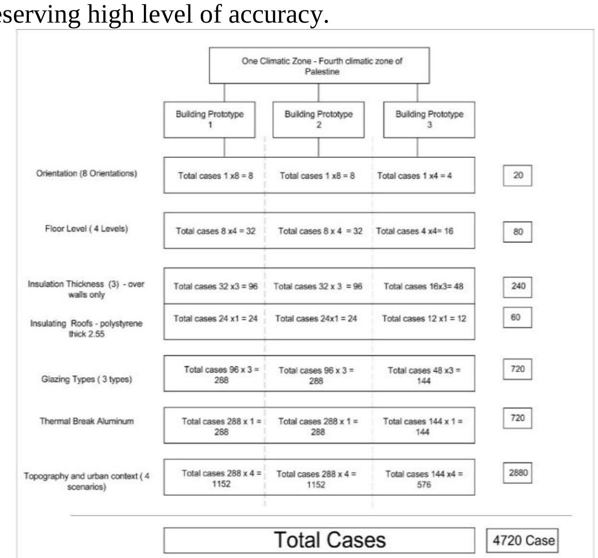

Figure 10. Overall cases of simulation

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4 TOOL DESCRIPTION

To address the tool objective, its interface presents a variety of drop-down menu icons related to building envelope passive design strategies. Upon executing the tool file, the main page that represents its interface appears as shown in figure 11. Input data will be found at the left edge of the tool interface as shown in Figure 12. Output categories (figure 13) can be divided into four categories. The first output is a building performance indicator in the form of a graph that indicates indoor air temperatures versus outdoor dry bulb temperature, and in comparison, with the comfort level range. The second output is energy consumption summary represented by monthly heating and cooling loads, as well as annual consumptions. The third output is a saving indicator describing how much energy can be saved as a result of the selected parameters in the form of Kilo watts hour energy (KWh) and in the form of money savings (Israeli Shekel ILS) as well as an indicator of how much money the homeowner needs to purchase the selected parameters (construction materials) in comparison with the generic wall design so as to compare cost with savings and to calculate the payback period. The fourth output gives an indication of how much energy needed to heat and cool the entire apartment in comparison to only heating the living space. The fifth category gives energy saving percentage indicator.

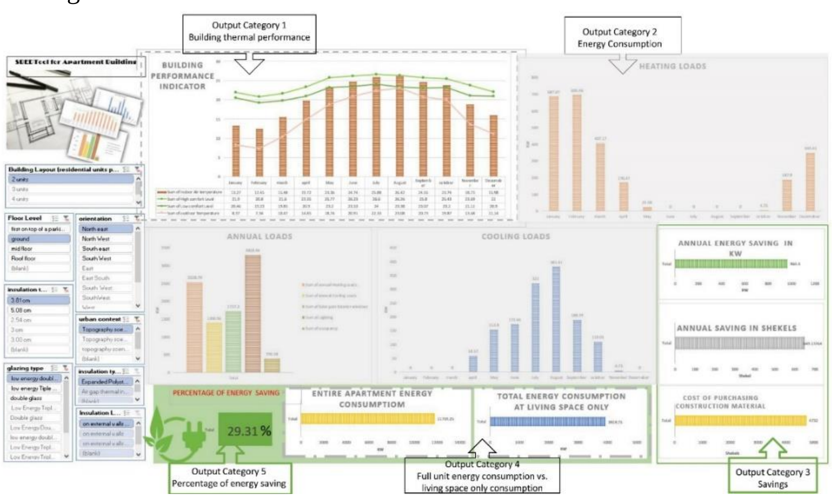

Figure 11. Tools interface and output categories

Figure 12. Tool input data

The use of parametric simulation is very important and is the main goal of this tool in order to analyse and compare results before taking design decisions. This tool allows to test unlimited options in building envelope parameters and has proved that such methodology can positively affect building performance and energy consumption.

5 CONCLUSION

The responsibility toward designing energy efficient buildings is increasing with the growing awareness and concerns of the preservation of natural resources. Simulation programs are seen very important tools to help designers evaluate the impact of their design decisions on building performance and on energy consumption. However, since such programs are expensive, time consuming and need expertise and detailed data to use, evaluating building performance has rarely been integrated in the building design process in many places around the world. This study focuses on the great need to integrate building simulation in the building design process by proposing a simplified tool that helps in meeting this goal.

The tool is helpful in guiding designers at early design phases as well as in helping architects with little experience in building simulation programs in testing the performance of their intended design in a fast and simple way. It also increased the knowledge and awareness toward designing envelopes that can be characterized as reduced energy envelopes for residential buildings in Palestine that accounts for the vast majority of energy consumption in building sectors.

Through the development and use of this proposed tool as well as resulting from the large simulation options conducted, the user can notice that:

1. Parametric simulation has shown great advantage in improving the thermal performance of buildings which leads to minimizing energy consumption. Testing building performance during early design phases can save 35 - 40% of total energy consumption in living spaces as well as in minimizing 15 – 17% of building total consumption which is a great percentage since building envelopes accounts for 40% of the energy consumption in buildings as has been clearly identified in the literature review.
2. The tool may allow the user to conduct cost-benefit analysis.
3. Economic evaluation of the building envelope design in comparison with the energy saving achieved by the implementation of the selected envelope design is very essential. Analysing and comparing results are the best evaluation process in choosing energy saving envelope.

The proposed assessment tool is intended to be used as guidelines during the design process as well as environmental assessment methodology rather than only a tool to evaluate building performance. Since the results have confirmed the importance of integrating building energy performance in the early architectural design decision. When aiming to design energy efficient buildings, it is very helpful to have some guidance toward which parameter that can make a large impact on energy performance.

REFERENCES

[1] Y. Bichiou and M. Krarti, "Optimization of envelope and HVAC systems selection for residential buildings," *Energy and Buildings,* vol. 43, no. 12, pp. 3373-3382, 2011.
[2] L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review on buildings energy consumption information," *Energy and buildings,* vol. 40, no. 3, pp. 394-398, 2008.
[3] T. D. Pettersen, "Variation of energy consumption in dwellings due to climate, building and inhabitants," *Energy and buildings,* vol. 21, no. 3, pp. 209-218, 1994.
[4] A. Enshassi, "Environmental concerns for construction growth in Gaza Strip," *Building and Environment,* vol. 35, no. 3, pp. 273-279, 2000.
[5] P. St. Clair and R. Hyde, "Towards a new model for climate responsive design at the university of the sunshine coast chancellery," *Journal of green building,* vol. 4, no. 3, pp. 3-20, 2009.
[6] P. Jatav, D. Rastogi, and D. M. Trivedi, "Energy saving in building by using energy efficient green building materials," ed: IRJMST, 2014.
[7] C. Younes, C. A. Shdid, and G. Bitsuamlak, "Air infiltration through building envelopes: A review," *Journal of Building physics,* vol. 35, no. 3, pp. 267-302, 2012.
[8] J. Feijó-Muñoz *et al.,* "Energy impact of the air infiltration in residential buildings in the Mediterranean area of Spain and the Canary islands," *Energy and Buildings,* vol. 188, pp. 226-238, 2019.
[9] S. N. Al-Saadi, "Envelope design for thermal comfort and reduced energy consumption in residential buildings," King Fahd University of Petroleum and Minerals, 2006.
[10] N. Said and H. Alsamamra, "An Overview of Green Buildings Potential in Palestine," *Energy,* vol. 8, no. 2, pp. 20-33, 2019.
[11] O. G. Santin, "Behavioural patterns and user profiles related to energy consumption for heating," *Energy and Buildings,* vol. 43, no. 10, pp. 2662-2672, 2011.
[12] S. Monna, "Integrated Approach for Intelligent Envelope Design: Simulation performance of building envelope design strategies and technologies during the early design stage," in *1st International Conference on Building Sustainability Assessment, At Porto, Portugal (10)*, 2012.
[13] A. S. Muhaisen and H. R. Dabboor, "Studying the impact of orientation, size, and glass material of windows on heating and cooling energy demand of the Gaza strip buildings," *Studying the Impact of Orientation, Size, and Glass Material of Windows on Heating and Cooling Energy Demand of the Gaza Strip Buildings,* vol. 27, 2013.
[14] A. Cicelsky and I. A. Meir, "Parametric analysis of environmentally responsive strategies for building envelopes specific for hot hyperarid regions," *Sustainable Cities and Society,* vol. 13, pp. 279-302, 2014.
[15] M. Arif, M. Katafygiotou, A. Mazroei, A. Kaushik, and E. Elsarrag, "Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature," *International Journal of Sustainable Built Environment,* vol. 5, no. 1, pp. 1-11, 2016.
[16] H. Khatib, "IEA World Energy Outlook 2010—A comment," *Energy policy,* vol. 39, no. 5, pp. 2507-2511, 2011.
[17] M. S. Ismail, M. Moghavvemi, and T. Mahlia, "Energy trends in Palestinian territories of West Bank and Gaza Strip: Possibilities for reducing the reliance on external energy sources," *Renewable and Sustainable Energy Reviews,* vol. 28, pp. 117-129, 2013.

[18] M. K. Ouda, "Analysis and Prediction of Household Energy Consumption in West Bank and Gaza Strip," *Islamic Univ. J.*, vol. 18, no. 1, pp. 77-98, 2010.
[19] M. M. Njore, "West Bank and Gaza-Energy efficiency action plan for 2020-2030," The World Bank, 2016.
[20] J. Yu, L. Tian, X. Xu, and J. Wang, "Evaluation on energy and thermal performance for office building envelope in different climate zones of China," *Energy and Buildings,* vol. 86, pp. 626-639, 2015.
[21] A. B. R. González, J. J. V. Díaz, A. J. Caamano, and M. R. Wilby, "Towards a universal energy efficiency index for buildings," *Energy and buildings,* vol. 43, no. 4, pp. 980-987, 2011.
[22] S. Goodhew and R. Griffiths, "Sustainable earth walls to meet the building regulations," *Energy and Buildings,* vol. 37, no. 5, pp. 451-459, 2005.
[23] S. Wijesuriya, M. Brandt, and P. C. Tabares-Velasco, "Parametric analysis of a residential building with phase change material (PCM)-enhanced drywall, precooling, and variable electric rates in a hot and dry climate," *Applied Energy,* vol. 222, pp. 497-514, 2018.
[24] T. Zhang, Y. Tan, H. Yang, and X. Zhang, "The application of air layers in building envelopes: A review," *Applied energy,* vol. 165, pp. 707-734, 2016.
[25] A. Aksamija, *Sustainable facades: Design methods for high-performance building envelopes*. John Wiley & Sons, 2013.
[26] A. Handbook, "Fundamentals, ASHRAE–American Society of Heating," *Ventilating and Air-Conditioning Engineers,* 2017.
[27] J. S. Gero, "Design prototypes: a knowledge representation schema for design," *AI magazine,* vol. 11, no. 4, pp. 26-26, 1990.
[28] R. Hudson, "Strategies for parametric design in architecture: an application of practice led research," University of Bath, 2010.
[29] A.-T. Nguyen, S. Reiter, and P. Rigo, "A review on simulation-based optimization methods applied to building performance analysis," *Applied Energy,* vol. 113, pp. 1043-1058, 2014.
[30] T. Østergård, R. L. Jensen, and S. E. Maagaard, "Building simulations supporting decision making in early design–A review," *Renewable and Sustainable Energy Reviews,* vol. 61, pp. 187-201, 2016.
[31] V. Lapinskiene and V. Martinaitis, "The framework of an optimization model for building envelope," *Procedia Engineering,* vol. 57, pp. 670-677, 2013.
[32] M. Ozel, "Effect of wall orientation on the optimum insulation thickness by using a dynamic method," *Applied Energy,* vol. 88, no. 7, pp. 2429-2435, 2011.
[33] N. Ardda, R. Mateus, and L. Bragança, "Methodology to Identify and Prioritise the Social Aspects to Be Considered in the Design of More Sustainable Residential Buildings—Application to a Developing Country," *Buildings,* vol. 8, no. 10, p. 130, 2018.
[34] M. Hadid, "Establishing, Adoption, and Implementation of Energy Codes for Building," *Architectural Styles Survey in Palestinian Territories,* 2002.
[35] R. De Dear, "Recent enhancements to the adaptive comfort standard in ASHRAE 55-2010," in *Proceedings of the 45th annual conference of the Architectural Science Association, Sydney, Australia*, 2011, pp. 16-19.
[36] A. Shariah, B. Shalabi, A. Rousan, and B. Tashtoush, "Effects of absorptance of external surfaces on heating and cooling loads of residential buildings in Jordan," *Energy Conversion and Management,* vol. 39, no. 3-4, pp. 273-284, 1998.
[37] A. Yezioro, B. Dong, and F. Leite, "An applied artificial intelligence approach towards assessing building performance simulation tools," *Energy and Buildings,* vol. 40, no. 4, pp. 612-620, 2008.
[38] A. Gasparella, G. Pernigotto, F. Cappelletti, P. Romagnoni, and P. Baggio, "Analysis and modelling of window and glazing systems energy performance for a well insulated residential building," *Energy and Buildings,* vol. 43, no. 4, pp. 1030-1037, 2011.
[39] A. Shariah, B. Tashtoush, and A. Rousan, "Cooling and heating loads in residential buildings in Jordan," *Energy and buildings,* vol. 26, no. 2, pp. 137-143, 1997.
[40] E. A. Othman and Y. S. Abughalion, "Developing HVAC Heating and Cooling Loads Calculation Rules of Thumb for Palestine," 2017.
[41] F. 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, 2016.
[42] M. Y. P. Siddhartha, "Effect of building orientation and window glazing on the energy consumption of HVAC system of an office building for different climate zones," *IJERT,* vol. 4, pp. 2278-0181, 2015.
[43] W. A. Friess and K. Rakhshan, "A review of passive envelope measures for improved building energy efficiency in the UAE," *Renewable and Sustainable Energy Reviews,* vol. 72, pp. 485-496, 2017.
[44] S. Mirrahimi, M. F. Mohamed, L. C. Haw, N. L. N. Ibrahim, W. F. M. Yusoff, and A. Aflaki, "The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate," *Renewable and Sustainable Energy Reviews,* vol. 53, pp. 1508-1519, 2016.
[45] H. Samuelson, S. Claussnitzer, A. Goyal, Y. Chen, and A. Romo-Castillo, "Parametric energy simulation in early design: High-rise residential buildings in urban contexts," *Building and Environment,* vol. 101, pp. 19-31, 2016.