The use of artificial intelligence (AI) and Big-Data to improve energy consumption in existing buildings

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Abstract. The use of Artificial Intelligence AI and Big data can contribute to improve energy performance in buildings. There are so many data are available in different institutions within a country such as Ministry of housing and electricity companies. The aim of this research is to propose a link between all these institutions with the aid of field measurement and occupants’ thermal sensation. The work used various methods to carry out this research including field measurement, computer modelling and survey. It was found that use of AI in existing buildings can improve energy performance significantly. The current research focused on optimization of WWR (Window to Wall Ratio) with orientation. WWR for western zones should not exceed 15% in extreme hot and humid climate and it can reduce energy consumption by 20%.

1. Introduction
Human performance is effected substantially by thermal comfort on the level of physical and mental [1]–[3]. One of the major reasons for this is that we are as human spends more than 90% of our times in doors. There are four major aspects contribute to the total health and productivity of people which are all linked to indoor environmental quality (IEQ): thermal comfort, visual comfort indoor air quality and acoustics (quality of sound and noise). Based on an abundant research publication and previous studies, there is no doubt that human thermal comfort is the most important aspect among all of them [4], [5]. Buildings consume roughly 40% of total energy globally to achieve thermal comfort [6]. As a result, thermal comfort is very linked to Artificial Intelligence AI to achieve comfort level with less amount of energy consumed [4], [7], [8]. In addition to that it can aid to increase productivity in living spaces indoor environment [9].

Figure 1. Location of residential zone in Jeddah
There are various methods used to investigate AI in buildings such as genetic programming, neural networks, fuzzy logic, heuristic search, computer software and many others. The use of AI is not only restricted and associated with thermal comfort, it is also linked to safety in buildings [10]. In a study conducted by [11] highlighted that AI to indoor thermal comfort. In addition to that, the work suggested that there are additional variables that can be further investigated such as lighting control especially when related to indoor luminance. The work of Orosa [12] presented a novel method based on Neural networks, it shows that a possible 20% of energy consumption in HVAC in buildings is possible utilising this system in order to achieve more comfortable indoor environment in summer. Another work conducted in tropical climate of Singapore [13] it showed that using neural network AI, it was found that 25°C is an ideal indoor temperature with minimum use in energy consumption. Marinakis [14] presented an investigation of use of internet of things for energy efficient buildings, it aids to improve reliable and effective policymaking in data-driven architecture. Paper also reported the importance of adaptation of big data such as Internet of things (IoT), distributed technology (DLT) and Artificial Intelligence (AI). BIM (Building Information Modelling) was found to be compatible with AI. BIM from mid of 1980s used to be part of AI. However, in the past five years start-up companies named it as Construction Tech [15].

2. Method and materials used

2.1. Location and case studies
The study was conducted in a residential building blocks located in the city of Jeddah (Figure 1). The climatic of the city is hot and humid with very hot temperatures in summer and warm in winter. The study selected two building blocks (Figure 2) which are consisting of five storeys, they comparable in size, building materials and differ in orientation with west and north orientations as identified in the figure.

2.2. Equipment used for monitoring and survey
This study is carried out using data-loggers for site monitoring for indoor air temperature and relative humidity. The field measurement and survey took place in the city of Jeddah on Jun 2020; the hottest months were targeted to obtain extreme results and feedback. In addition to that, a survey for selected families was conducted to obtain thermal comfort sensation in air-conditioning operation mode. There were about 18 families were asked on site to observe thermal comfort level for two different apartments with west and north orientations.
2.3. Computer modeling

The computer modeling software TAS EDSL was used for energy evaluation performance. It is also used to calculate amount of solar energy in two different facing properties.

3. Discussion and results

Results of data-loggers (Figure 3) indicate that there is a clear influence of orientation in residential buildings in hot regions. The monitoring took place for seven days of duration with a slot of an empty property to have the AC system switch off to be in the free running mode. It can be noticed that in the north facing apartment, the indoor temperature reached only 33.1°C while in west direction reached as high as 35.5°C. This is due to direct exposure to solar radiation on the west orientation which is considered as one of the worst in hot regions [16], [17]. Humidity also affected by raise of indoor temperature in reverse relation, it will impact the state of human thermal comfort and hence, amount of energy used in buildings. This can be seen in Figure 4 where total amount of energy used in the selected apartments are presented. It was found that there is an increase in west apartment compared to north by 20%. It has to be mentioned that both area and family size of two sleeted apartments were comparable.

Thermal comfort votes PMV (Predicted Mean Vote) also investigated as it can be noted in Figure 5. The feedback of occupants was taken during the operation of air-conditioning system. However, the west facing apartment influenced to thermal comfort due to heat gain from external envelope in the west facades from external walls as well as glazing system which is responsible for considerable amount of energy consumed. As a result, it is recommended that WWR in western facing rooms should be minimized to only allow adequate amount of daylight. In the work of Alwetaishi [17] WWR should not exceed 20%, in fact, this study is conducted in a hot region but it was a high altitude mountains, in a more heated outdoor condition like the case in the city of Jeddah, WWR should not exceed 15% which is quite similar to the recommendations of a study conducted in the city of Riyadh [16]. Figure 6 shows the amount of solar of both north and west. Size of windows in this region is very crucial and should be determined precisely.

Proposed system (Figure 7) present a new and innovative approach to control and provide a dynamic solution for architectural early stage wrong decision such as window to wall ratio. This can also be implemented on larger number of architectural elements such as thermal insulation, shading devices and thermal leakage. The system relies on AI and use of big data provided in the form of amount of electricity used by each property in a residential area. This can be formed by Ministry of housing which can group each area based on size of property and family members. MH then will identify each family member who is above average level of energy use to be reported to Sustainable Building Section (SBS). They have a lot of experts who can propose recommendations to improve energy performance of each property based on thermal comfort survey feedback conducted remotely. The system can contribute significantly on improving the energy performance as well as thermal comfort level for occupants.
Figure 4. Energy consumption in the two facing apartments, kWh

Figure 5. PMV of occupants based with operative system

Figure 6. Solar heat gain in north and west facing zones in summer
4. Conclusion
This study investigated the potential to apply AI to improve energy performance as well as thermal comfort using new system utilizing “big data” and AI. There are several institutions which are involved starting from Ministry of housing which has the responsibility to obtain energy consumption for all properties and submit them to sustainable building section. The SBS can study the data based on micro-locations and size of property as well as family. Field visit might be included to observe architectural and conduction condition. In the current investigated properties, west and north facing apartments were presented. It was found that amount of energy consumed in the west facing apartment was higher by 20%. It is suggested that WWR of western facing zones should not be greater than 15% in extreme hot regions such as in Jeddah where outdoor temperatures can get higher than 40°C in daytime during summer.

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