The role of simulation in design of high-performance buildings in Turkey

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Abstract. This paper reports on an exploration of the current role of building performance simulation tools in the building and HVAC design process. The focus of the study is on the design of high-performance buildings; our hypothesis is that this is the leading edge of building design, where simulation is most likely to be used to its full potential. The methodology underlying the paper consists of surveys with architects and engineers who carried out the design of a number of high-profile buildings. The paper adds to a small body of work that, over the years, has monitored the actual role of simulation in design. Whilst a lot of work is carried out to improve the role of simulation in design, especially the early phases, the real uptake and role of the technology may not always match our expectations. Critical review of the actual role of simulation tools remains necessary to assess progress and needs for further development. Results show that simulation is regularly used in building design projects, by a range of actors. However, the use of simulation efforts seems to be mainly the confirmation of expectations and the demonstration of meeting targets, especially those that are relevant for certification schemes. Building simulation still has unused potential in terms of selection of design alternatives from extensive search or option spaces. The use of more advanced techniques such as optimization in industry remains relatively low; work on uncertainty and sensitivity is not often undertaken in practice.

Keywords. high performance buildings, building performance simulation, integrated design, Turkiye
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1. Introduction

Since the studies on the use of building simulation in building and HVAC design began to emerge, three important observations have been made in almost all contributions: i) Simulation is important for designers not only in testing current ideas, but also in developing and presenting new ideas; ii) Simulation is often used in the final stage of the design process as a "performance confirmation" [1-4]. However, in the early stages of design, it is possible to test many more options with easy returns, iii) Integrated design of buildings and systems must be carried out by an interdisciplinary team, and simulation should also be considered as a very important technology for ensuring communication between different disciplines [5-10].

However, from the perspective of practitioners, it cannot always be said that the approach to simulation-assisted design has met at the expectations of teamwork practice. Various studies were conducted to explore the professionals' practice and wishes in last 15-20 years [11-14]. It can be said that most of the issues emphasized by those works are still valid after almost two decades.

This paper reports on an exploration of the current role of building performance simulation tools in the building design process in order to explore progress on the role of simulation. The focus of the study is on the design of high-performance buildings; our hypothesis is that this is the leading edge of building design, where simulation is most likely to be used to its full potential. The methodology underlying the paper consists of interviews with architects and engineers who carried out the design of a number of high-profile buildings. The research hones in on the situation Turkey, one of the MINT countries (Mexico, Indonesia, Nigeria, Turkey) who are seen as emerging economic powerhouses in the world economy [15].

2. Current Knowledge

In current Turkish literature, high building performance does not have a strict definition that can be compared to the international interpretations.

Instead, the prominent terminology used in the country refers to green buildings or sustainable buildings. When searching academic literature, internet and professional magazines for high performance buildings one can find buildings with some form of corresponding certificate such as LEED, BREEAM and similar. Generally, projects that have implemented some form of high-performance design strategies are driven by the need to meet the relevant performance requirements when applying for the required certificate. Since 2011, when Turkey first introduced LEED certification, and since 2012 when some buildings started to be BREEAM-certified, 514 buildings with a variety of functions and different sizes have been certified in total [16,17] (see Figure 1) There are 74 BREEAM certified buildings with several functions and 440 LEED certified buildings. When looking in detail at the statistics of the LEED certified buildings, 65% of these buildings are commercial, 22% are residential and the rest has several other functions such as hospital, hotel, education, mixed use, etc. Similarly, 65 % of BREEAM certified buildings are commercial, but BREEAM certified residential buildings are only 7 % of total certification in Turkey. The graph shows the state of art at Turkey in detail. Among LEED certified buildings, 66% are Gold, 14% are Silver and 12% are Platinum. The distribution of the certificate types of BREEAM buildings is more homogenous with 32% rated as Very good, 27% Excellent, 20% are Outstanding and 16% are Good.

According to the statistical reports and analysis efforts on current building stock presented by TUIK (Turkish Statistical Institute) [18] there are more than 11 million buildings in Turkey by 2020. From this point of view, the total number of certified buildings covers only 0.004% of the total stock. Over the last 10 years, especially in the "Terms of Refence (ToR)" of international construction consortia for major projects (for instance city hospitals, multinational company headquarters, or service buildings developed by foreign investors), several statements about building performance have been included, although legally they are not compulsory in Turkey. A wide body of literature, including dissertations, journal articles, conference papers and reports that address green buildings, sustainable architecture and energy efficiency of buildings in Turkey are available. Most of those studies have been focusing on energy efficiency which is still a hot topic for the region. The best cases and adaptation of regulations are usually referring to EU norms and applications. Technical reports and information documents have been prepared by the relevant units of the Ministry of Environment and Urbanization and the Ministry of Energy [19-21].

The background of the current knowledge of practice and professionals' perspective in Turkey is based on the evaluation of two previous studies [22, 23]. The first of these studies is the discussion of improved process management for the design of high-performance buildings through the use of design concepts in the pre-design stage in the paper prepared 13 years ago on this subject. The most important expectations of those was an opportunity to develop an environment that collects architectural idea and engineering idea in the same platform. This is an iterative process but at the end this platform helps to communicate the ideas in the same language. This attempt will also shift the program of requirement of the project to another specific or unique list based on the context of the project [22] (Figure-2).

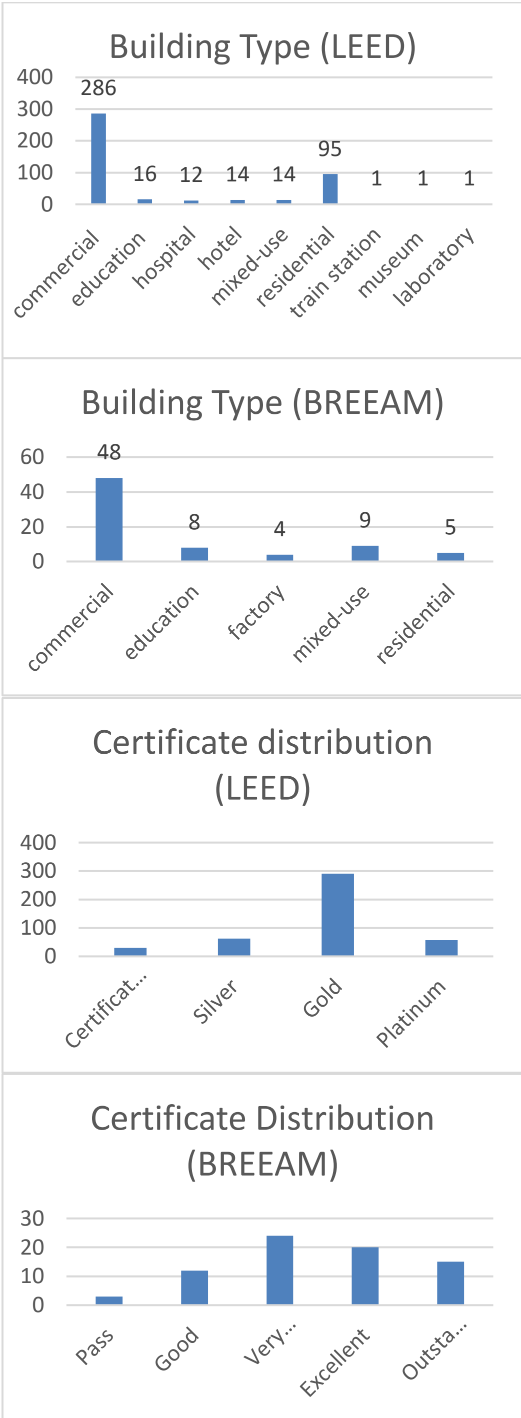

Fig.1- Statistics of LEED and BREEAM certified buildings in Turkey – distribution of building and certification types

Later, a paper presented in 2018 revealed the results of a survey conducted among professionals in Turkey [23]. In this study, 42 participants' views on building performance simulations were discussed under three titles: i) professional wishes, ii) barriers iii) future expectations. The brief of the responses to those three titles are at below.

The first collected responses for finding out professionals' wishes/expectations were mainly focus on the practical use of performance simulations. They were aware of the importance of the use of performance evaluation in any level of design process as long as the tools were easily accessible, user friendly, accurate enough and cost effective. On the other hand, the drawbacks they listed as barriers are;

- Software costs (buy, update, maintenance, etc.)
- Choosing right one among many options needs education and experience
- Lack of technological awareness
- Incompatibility with Turkish legislations
- No feedback to design process

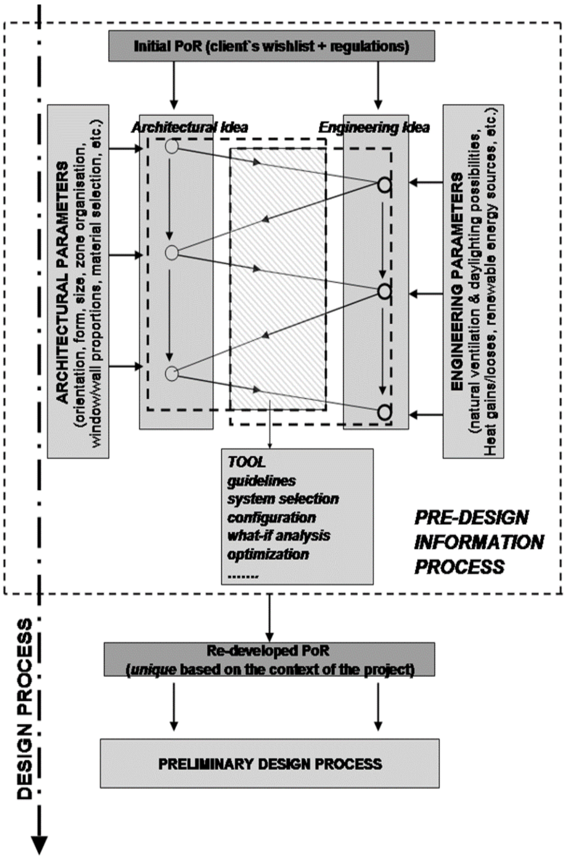

Fig.2- Pre-design information process flow chart [22]

The professionals had thoughts on dissemination of practically use of performance simulations in the future. The first expectation was enhancing undergraduate education and include courses on performance simulations. Those educations should continue after graduation as continuous professional development. Cost of the tools was a basic problem which needs to be solved in the near future. The support of government by encouraging the use of simulation by regulations and codes is another requirement stated by the professionals.

3. Methodology

In this paper, two specific further issues are evaluated. One of them is to understand the application practices of high performance building (HPB) design, and the second is to evaluate the role of simulation use in these applications. This study consists of compilations of interviews done with architects of large-scale and multifunctional buildings in Turkey and with engineers have taken part in similar projects. During the interview, local practices and approaches encountered in international projects were compared and evaluated. The interviews were done between January-March 2021 via an online platform (zoom). The interviewees were informed about the reason of the interview and the content was delivered before zoom meeting. Each of the zoom session was recorded. The questions are mainly open ended in order to make interviewees feel free to express their design practices.

3.1 Interviews

The interviews were done with six designer architects, five HVAC engineers and one engineer working at a ministry in a decision-making position (Picture 1). Thus, information was obtained not only about the routine design and application process but also about the way of execution and requirements of legal procedure which Turkish governmental bodies expect. Similar questions were asked during the interviews, and the answers received were grouped under four main headings.: i) high performance building experience ii) interdisciplinary team work and integrated design, iii) computer simulation applications iv) opportunities/challenges on designing HPB.

Picture.1- Screenshots of online interviews

4. Results

4.1 High performance buildings

In general all the interviewees have an opinion on High Performance Buildings but their definitions vary significantly. The common consent on the definition is that such buildings should be energy efficient and sustainable. Architects with international experience provide broader definition than those working nationally. This wider definition includes user health, comfort and safety. Although there is no significant difference between the definitions of engineers and those of architects, it is easier for engineers to describe the technical approach.

While defining high performance buildings, it is seen that engineers' and architects' perspective were different. The comments of engineers and architects are listed separately here, in order to acquire the difference.

Engineers defined "high-performance buildings" as follows:

- A building which maximises energy and comfort,

- It is not only an energy efficient building, but also maximizes indoor air quality, acoustics, lighting, ventilation, selection of materials used, carbon footprint and lifetime cost analysis,

- Designed, built, operated and efficient use of resources in accordance with international standards,

- The buildings which their envelope is designed with specific consideration, and

- Buildings where electrical and mechanical systems are applied efficiently and comfortably

In addition, the engineers added the following to their thoughts on the high-performance building:

- High-performance building features should be legal and compulsory for all buildings,

- High performance buildings need to renew themselves with technology because today's high performance may be tomorrow's weak performance,

- It was also stated that occupants should feel the same comfort at the whole lifespan of high-performance buildings.

On the other hand, architects defined "high-performance buildings" as follows;

- Able to interact dynamically with its environment,

- The buildings that closest to nature,

- Being sustainable, functional, aesthetic, cost effective, easy to access, safe and giving importance to historical preservation,

- Self-sufficient buildings,

- It is described as a building where the right technology is used with the right consultants.

In addition, it was mentioned that high-performance building is a consciousness and should be defined as a sustainable and accessible goal.

Considering the interviewees' HPB design experience, it is understood that the building cases in which they have the experience are mostly projects produced abroad and dependent on international procedures, or projects carried out domestically but also carried out by international consortiums and subject to special specifications. It does not seem possible to talk about HPB principles in smaller scale projects that follow local procedures.

4.2 Interdisciplinary team-work and integrated design

When asked about the interdisciplinary work practice and frequency of the experts interviewed, they all mention the importance of interdisciplinary work. Here, it can be said that engineers attach more importance to collaboration with architects than architects themselves attach to working with engineers. However, in terms of implementation practice, it is understood that the process can be progressed in cooperation with all stakeholders from the beginning of the design process. This is not so often in local projects but mostly when an international consortium drives the process. Although the importance of integrated design is acknowledged by all participants, it is seen that engineers are more open here as well.

4.3. Computer simulation applications

The tools used in design process vary. Architects use computer applications throughout in the design process. However, with the widespread use of BIM, it was stated that commercial tools such as Autodesk REVIT and Rhino programs were preferred in most architectural offices. For energy analysis by engineering companies, it emerged that Energy Plus, EDSL Task, E-Quest, Design Builder and Carrier programs are preferred. For lighting analysis, the DiaLux program was generally used. Regarding to usage of these tools, mostly those are not seen as a 'design tool'. Frequently it is accepted that the concept design is under the responsibility of architects and energy analysis done by engineers seems as "next step" during which tools are used just for performance confirmation.

BIM applications are seen as an important platform that enables all the team in the consortium to work together in international projects. However, it is understood that the possibilities provided by BIM are more effectively employed within engineering services, whilst in the architectural process possibilities beyond visualization are not yet used. No simulation software is used for performance evaluation in architectural offices in Turkey. However, expertise support is required when necessary. An architectural office, which has only established its own interdisciplinary teams, makes it possible to carry out the project with instant analysis and simulation support throughout the entire design process. In engineering offices, calculation tools are used to determine the capacity of the mechanical installation. It has been stated that international projects should benefit from various simulation applications when they are included in the process from the beginning as part of the design team.

The interviews generally focused on BIM. The advantages and disadvantages of BIM system were mentioned as follows:
Advantages:

- All disciplines are studied on the same model,
- Plan, section, elevation, etc. concurrently organized during the design phase,
- The problems previously encountered during the construction are solved during the design phase,
- Specifications of the materials and components can be loaded as library information and this information can be used in different phases later,
- The pre-concept stage and the final delivery file are usually in the same file,
- BIM allows to perform various analyses on the model if required.

Disadvantages:

- An expensive and complex system,
- There are still a few experienced people in the market
- A lot of time, people, costs and equipment are required,
- It is stated that the professional experience requirement of BIM will increase as the m^2 of the building grows

Regarding the opinions of the professionals listed above on BIM, it is obviously seen that, in practice, they usually use BIM in its basic level (up to LOD-300). Advanced usage is rarely a necessity, particularly if the process is proceeded by international consortium. On the other hand, BIM has a great potential on the passive and active measures identified by Krygiel and Nies [24]. The sustainable BIM approach has been reduced and listed in accordance with the possibilities that BIM can provide at the early design stage are; i) building orientation, ii) building massing, iii) solar and shadow analysis, iv) conceptual energy modelling and v) potential renewable energy analysis. However, none of the professional declares a plug-in that is used in BIM for performance evaluation in early design stage.

The professionals were also asked to compare practice of BIM in local applications and international projects. According to their opinions, in Turkey, there is high costs level for BIM applications that small and medium companies cannot afford easily. Becoming an expert needs time and extra effort which makes it difficult to get used to this system. The architecture and engineering offices that have started to implement 3D in BIM platform provides maximum benefit in terms of the quality, standard and time given to the design. On the other hand, if the collaborative offices do not use BIM models and provide only 2D drawings; it was stated that this causes to lost time and effort while converting the models into 3D models. It was mentioned that governmental bodies are not force public sector to use several software mandatorily as licensing of many of them are too expensive but supported/encouraged the use of programs such as BIM.

Professionals mentioned that during the international consortium projects, it is easier to switch to the BIM system due to such requirements/obligations in the tender. International marketing competitions also lead to use BIM platforms.

4.4. Opportunities and challenges when designing HPB

There are various opinions about the value of high performance buildings, and the process of designing them. Although there is a common view that there will be an important opportunity and that energy efficient and environmentally friendly buildings will increase, only a few participants made a value definition by taking into account user comfort, health and safety. To the question posed about the challenges and limitations of the design process of such buildings, all participants defined two issues as constraints: cost and legal procedure. In the case that the future user of the building is the client, the payback period of the initial investment cost that increases due to HPB applications can be significant and the client can be convinced. In terms of legal procedure, if the expected performance is not clearly defined in the tender files and specifications, it is stated that sufficient implementation cannot be made in this regard. On the other hand, the expert who gave his opinion from the Ministry stated that the specifications for governmental structures were prepared very carefully and in detail, but they do not have control powers in special applications. Therefore, a comprehensive legal regulation is required.

5. Conclusions

In general, High Performance Buildings represent a category of buildings that are designed and engineered to be energy efficient, limit greenhouse gas emissions, and make efficient use of other resources such as water and materials. Typically these buildings benefit society, productivity, and the health and wellbeing of vulnerable members of the population [25].

The design of High Performance Buildings is based on a systematic exploration of design options, use of simulation tools to predict building behaviour, and rational decision making. Often the design process involves the concept of 'integral design'. System thinking and system engineering are seen as core contributors to success [26,27].

For more than two decades, performance-based evaluation of the design process, integration of building simulation programs into the process, the approach of professionals to this issue and what can be done in practice to improve the design process have been discussed. Although these requirements differ for each country and region, it is based on the understanding of the process by architects and engineers, who are two important members of the design team. In this study, it is questioned how the subject is still perceived by professionals in Turkey, and it is stated that nothing much has changed in practice, by referring to similar studies conducted in the past.

A new perspective to HPB will have a strong contribution to changing the lives of particularly vulnerable and low-income populations in Turkey. This part of society will be most strongly affected by climate change and scarcity of resources. The necessity for high performance buildings will address built environment challenges in terms of the need to cope with population growth, scarcity of resources (energy, water, material), climate change (global warming and extreme events), environmental protection and their side effects on economic fluctuation and social transformation.
A further study with more participants on high performance buildings' practice is going on. It is aimed to scrutinise a new perspective to the current understanding of practitioners by taking into consideration climate change adaptation and embodied carbon mitigation. By this study it is supposed that a step change shall be possible in thinking about building performance in Turkey and the wider region, changing building design, engineering and construction practice.

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Data Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.