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Life Cycle Assessment with BIM Towards Sustainable Energy Policy-Making: The Case of Urban Transformation in Istanbul

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Abstract: Buildings are responsible for almost forty percent of global energy. Due to their high consumption of energy, buildings are on the front line of sustainability researches. In Turkey, six million out of twenty-two million buildings need to be demolished and rebuilt to meet seismic standards. These buildings are also far below the standards in terms of energy efficiency. Therefore, urban transformation can be thought of as a great opportunity for energy efficiency. This study investigates four things: (i) the energy-efficient urban transformation strategy in Gaziosmanpaşa-Istanbul region, which is selected as a case study; (ii) the effect of energy efficiency in this market; (iii) the adequacy of energy standards of Turkey; and (iv) contribution of digitalization in construction to sustainability with Building Information Modelling (BIM) and energy analysis. According to the energy efficiency scenarios, energy analyses were carried out on the BIM model. The most cost-effective strategy was determined with the Life Cycle Cost method. When compared with the current situation, it is possible to save energy up to 227 GWh a year, which is equal to the annual heating energy demand of approximately 30,000 housing, in the case study area with the most efficient scenario to be realized.

Keywords: Urban transformation, sustainability, building information modelling, life cycle assessment, energy policy

1. Introduction

Because of high demand and unsustainable supply of energy, energy efficiency has been becoming more and more crucial. Energy markets by nature have serious implications from household budgets to international relations. Approximately forty percent of global energy consumption is composed of buildings (International Energy Agency, 2019). Due to their high consumption of energy, buildings are on the front lines of the energy efficiency researches. Therefore, it is clear that the correct implementation of building energy efficiency policies will have a great positive impact from an economic and environmental point of view. In many developing countries, the urban transformation has been a popular theme in recent years as a precaution of natural disasters or various poor comfort conditions. According to a statement from the authorities, six million out of twenty-two million buildings nationwide needs demolishing and

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rebuilding to meet seismic standards in Turkey. Two million of these six million buildings are located in Istanbul, and approximately twenty-five percent of two million must be demolished and rebuilt urgently within five years. It is clear that these buildings are also far below the standards in terms of energy efficiency. Therefore, urban transformation in Istanbul also can be thought to be a great opportunity for energy efficiency. Considering these explanations, the main object of the study is to reveal the energy efficiency potential of the urban transformation by using digital tools in the construction industry. For this purpose, the study concentrates on the dwellings and performs energy analyses using building information modelling according to different scenarios. Also, these scenarios help to develop sustainable energy policy-making and to find out the economic benefits of the energy-savings with life cycle cost approach using net present value analysis.

This study consists of five sections including introduction, literature review, methodology, results and conclusion. In the second part, comprehensive literature research which deals with subject and methodology is discussed separately. The methodology of the study is explained in detail in section three, and the selection of region and representative buildings is given in this context. Section four presents the results of analyses in the aspect of energy and cost, and finally, section five includes the conclusion part which evaluates the results of the study. Also, Figure 1 shows the flowchart explanation of the proposed study approach.

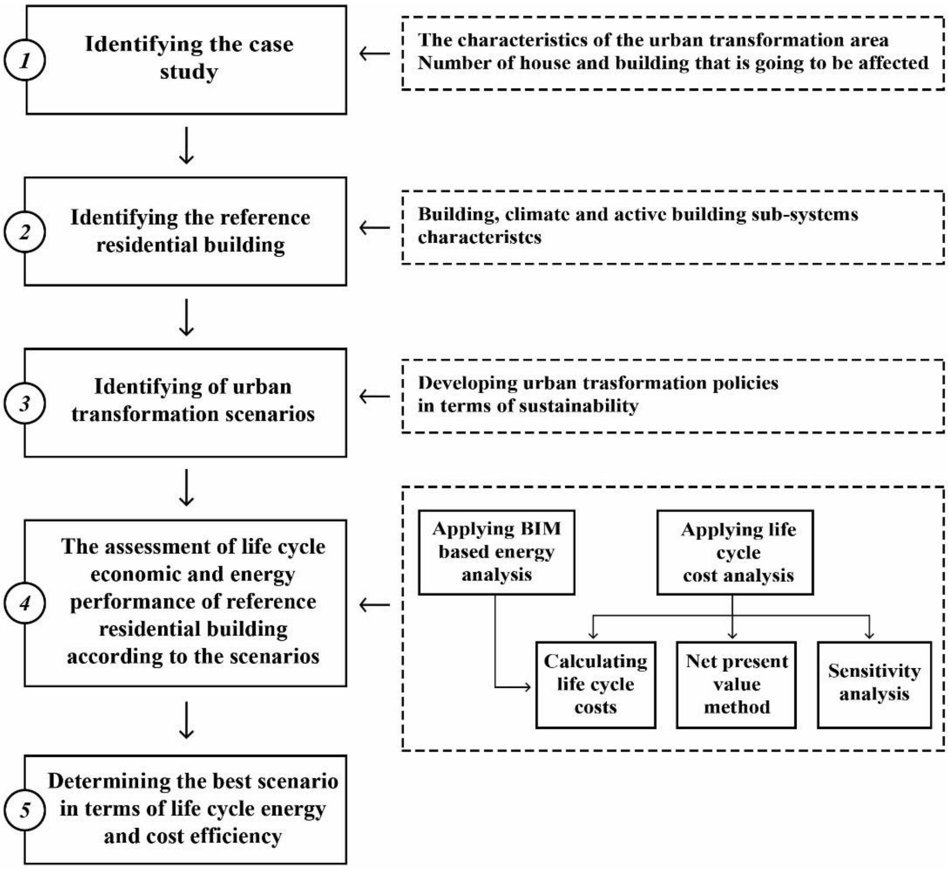

Fig. 1 - The flowchart explanation of the proposed study approach

2. Literature Survey

This section presents a review of the related studies starting with subject survey and followed by method survey consisting of building information modelling based performance analysis and life cycle analysis.

2.1 Subject Survey

In recent years, the energy efficiency of buildings has been studied extensively because it is a fact that energy efficiency is one of the keys toward sustainable development. Jakob (2006) aimed at quantifying the marginal costs of energy efficiency investments which is a key element of investment decision-making of new buildings or the refurbishment of existing buildings. The paper showed, for the first time, co-benefits of energy efficiency investments, of which decision-makers in the real estate sector, politics and administrations are scarcely aware. In terms of energy efficiency, the design and energy policies of buildings have become more important. Russell-Smith et al. (2015) demonstrated that buildings could be designed to perform at higher environmental standards than those designed without a target in place by combining life cycle assessment and target value design. Also, Yu et al. (2017) support that without building energy policies, in Gujarat, building energy use would increase by 15 times in commercial buildings and four times in urban residential buildings between 2010 and 2050 without building energy policies. Longo, Montana and Sanseverino (2019) presented a review on optimization of low-energy buildings design to collect the results of previous works and to guide new designers.

One of the most studied topics on energy efficiency is the economic and environmental impact of the energy-efficient renovation of buildings. Pikas et al. (2015) investigated economic benefits of a renovation of apartment buildings, including tax revenue, job generation, and disposable net income per 1M€ of investment, and energy savings on both an individual and national level. The study shows that investment in energy efficiency provides both environmental and economic benefits on an individual and government. This study differs from others by taking into account indirect economic contributions.

Aguacil et al. (2017) focused on the Spanish residential building stock built until 2001, which has a low level of energy performance. According to the paper, renovating the built environment provides huge energy saving potential in Spain. Mangan and Oral (2016) intended to evaluate the effective measures for improving the energy performance of housing for different climate zones in Turkey. Regarding these alternative measures, the life cycle was used to evaluate the energy, economic and environmental performance of the residential buildings. The study which claims that it can produce data for the relevant regulations in the design of new residential buildings or in the improvement of existing buildings will add value to our study. Pombo et al. (2019) aimed at the assessment of energy-saving measures in terms of sustainability and demonstrate that current renovation strategies that are being applied in Madrid are far from being optimal solutions. Accordingly, the obtained life cycle environmental and financial savings is relatively high, considering the required additional investment. Mikulić, Bakarić and Slijepčević (2016) aimed to estimate the effects of energy investments in residential and public buildings in Croatia. Pombo, Rivela and Neila (2019) demonstrate the key role of life cycle thinking in the design of sustainable development policies and in the design of optimal retrofit solutions. In this study, alternative housing renewal policies were investigated in terms of energy efficiency and cost in three climate regions in Spain. As a result, it is shown that the appropriate policy to be applied in three different climate regions should be different. Although this study examines renewal policies in different climates, the impact on our work in terms of alternative policies is important.

Sartori and Calmon (2019) explored energy consumption and greenhouse gas emissions by simulating five sustainable retrofit measures in two typical neighbourhoods located in the city of Vitória in the province of Espírito Santo, Brazil. This study will serve as a model for our study in terms of the scale it analyzes. Moreover, several important studies have performed cost-benefit analysis for the energy efficiency retrofit of existing buildings and revealed important data in many aspects such as energy policies, climate zones and energy prices (Liu et al., 2018) (Oregi, Hernandez & Hernandez, 2017) (Amstalden et al., 2007).

Another important subject to be investigated in the energy efficiency of buildings is the energy-efficient design of new buildings and their environmental and economic benefits. Morrissey and Horne (2011) applied a life cycle costing approach to investigate the impacts of energy efficiency measures for new residential buildings in a cool temperate climate, Melbourne Victoria. The results of the research claimed that the most effective residential building design is always more energy efficient than the current energy code requirements, for the full time considered. This result provides important data in terms of the energy efficiency scenarios that we propose in our study. Kneifel (2010) aimed to estimate life-cycle energy savings, carbon emission reduction, and cost-effectiveness of energy efficiency measures in new commercial buildings in the U.S. The study is important in terms of taking into consideration the cost of construction, although it is research for commercial buildings. Also, Weiler, Harter and Eicker (2017) claimed that the highest building refurbishment standard resulted in the best life cycle performance when compared with less ambitious refurbishment or construction of a new building of today's standards. How the construction of a new building is analyzed can create the infrastructure of our study, although the purpose of the study is different. Krarti and Dubey (2018) analyzed the cost savings potential for designing and retrofitting residential buildings to be energy-efficient in Bahrain. According to the study, the energy savings of buildings, as well as the country, can reach up to 320 GWh in annual electricity consumption and 87 M.W. in peak demand by developing and enforcing of a more stringent building energy efficiency code.

Invidiata, Lavagna and Ghisi (2018) aimed to select the best design strategies to improve the sustainability of buildings by combining adaptive thermal comfort, climate change, life cycle assessment, life cycle cost analysis and multi-criteria decision making. In addition to the aim of the study, the results claimed that there would be an average increase of 53% in the cooling energy demand and a decrease of 49% in the heating energy demand in 2080 compared to the consumption in 2017. Additionally, Smeds and Wall (2007) and Yilmaz (2007) demonstrated the importance of energy-efficient design strategies in different climate conditions.

Moreover, the reference building in the energy efficiency analysis is very important in terms of reflecting the reality of the analysis. Ballarini, Corgnati and Corrado (2014) present a methodology for the identification of reference buildings to assess the energy-saving potentials of the residential building stock. Although cost analyses are not in the scope of Ballarini's study, the results form a basis for further investigations related to building energy efficiency.

2.2 Method Survey

BIM Based Performance Analysis. Building performance simulations are an essential part of the design process for energy-efficient and high-performance buildings. According to Wang and Fan (2013), BIM is one of the most important topics in sustainable building design in recent years. Also, Liu, Meng and Tam (2015) aimed to develop a BIM-based building design optimization model for sustainability and states that BIM provides an ability to do the simulation for verifying the performance of design schemes. In recent years, a lot of researches have been done on BIM-based energy efficiency. Chong, Lee and W (2017) presented a mixed review of the adoption of BIM for sustainability and Eleftheriadis, Mumovic and Greening (2017) produced a review study of current developments and future outlooks based on BIM capabilities in terms of life cycle energy efficiency in building structures. Moreover, Soust-Verdaguer, Llatas and García-Martínez (2017) presented a critical review of BIM-based life cycle assessment method to buildings. BIM also started to play an important role in both the design and construction stage in Turkey, and it is expected that usage of it is going to become wider. Moreover, BIM enables sustainable design possibility and energy efficiency measurements to architects and engineers without using any different program. It is very likely to use BIM in urban transformation projects in the future in Turkey. Hence, BIM-based energy analysis is a significant part of our study.

Life Cycle Cost Approach. Life-cycle cost analysis is an economic evaluation tool to determine the most cost-effective option among different investment alternatives by taking into consideration cost and saving associated with each alternative along a period of analysis (Kirk & Dell'Isola, 1995) (Bull, 2003) (Cole & Sterner, 2000). Also, Flanagan et al. (1989) stated that the technique can help decision-making for building investment projects. In the construction industry, the life cycle cost approach has been studied for a long time, and extensive researches and reports have been developed. Accordingly, Islam, Jollands and Setunge (2015) presented a detailed review of life cycle assessment and life cycle cost implication of residential buildings. Additionally, Mangan and Oral (2016), which uses life cycle cost approach are taken as a basis in the framework of this study. From the energy perspective, the effect of energy efficiency on life cycle costs will play an important role in our study. Accordingly, there are significant researches that reveal the importance of energy efficiency. Dwaikat and Ali (2018) claimed that the future costs of the investigated green building are around 3.6 times as high as its initial design and construction costs by using life cycle analysis. Moreover, the cost of energy accounts for 48% of the total life cycle budget for the building.

3. Methodology

Since the purpose of the study to reveal the energy efficiency potential of the urban transformation, energy analyses according to efficiency scenarios constitute the main part of this section. The study focuses on the specific city and district area to obtain more realistic results with energy analyses. Also, reference buildings are determined for analyses according to district building topology and policy and works of the Housing Development Administration of Turkey. These analyses are carried out using building information modelling to demonstrate the importance of the digitalization of the construction. Finally, life cycle cost approach is applied to find out the economic advantage of the proposed scenarios.

3.1 Selection of City and District

After the 1999 earthquake in Kocaeli, it was revealed by many studies that it is likely to have an earthquake that would greatly affect Istanbul (Le Pichon, Sengor & Taymaz, 1999). However, it is clear that a lot of structures are not ready for the earthquake in different parts of Istanbul. Because of this situation, the urban transformation movement in Istanbul is increasing rapidly in recent years. According to the Turkey Ministry of Environment and Urbanization, in Gaziosmanpaşa district, there are more built-up areas which are risky in terms of the earthquake than any other district (Ministry of Environment and Urbanization of Turkish Republic, n.d.). Gaziosmanpaşa district is located on the European side of Istanbul and, is one of the most populous districts of Istanbul with a population of 400.000. In 2013, 432 Hectares of the district with a total area of 1173 hectares were declared risky areas and the urban transformation process was started in 13 different regions (Gaziosmanpaşa Municipality, n.d.). According to the official website of the Gaziosmanpaşa Municipality, Table 1 shows the number of buildings to be affected within the scope of urban transformation according to the regions.

Table 1 - The number of building and housing to be affected by urban transformation according to the municipality data

Regions	Quarter Names	Number of Building	Number of Housing
1	Merkez	157	439
2	Sangöl Merkez	256	393
3, 4	Pazariçi	1,808	5,929
5, 6A, 6B, 6D	Yıldıztabya, Yenidoğan	1,543	3,744
7A, 7B	Bağlarbaşı	526	960

9A, 9B	Yeni	281	2,039
10A, 10B, 10C	Barbaros Hayrettin Paşa	1,961	10,779
11A	Mevlana	246	2,837
12B, 12C	Sangöl	523	1,059
13	Bağlarbaşı	214	627
	Slums Prevention Region	81	108
Total		**7,596**	**28,914**

3.2 Determination of the Reference Buildings

It is an important and difficult subject to determine a model structure that can represent the whole region due to the diversity of buildings and complex settlement. Also, both existing buildings and new buildings to replace old buildings within the scope of urban transformation are discussed in our study. In parallel with this, the new building projects published by Gaziosmanpaşa Municipality and the current building structure of the region have been examined separately. Accordingly, it is obvious that new projects prepared within the scope of urban transformation conflict with old structures. In the context of urban transformation, this can be considered as a natural outcome. Because of these reasons, two reference buildings are determined in order to represent existing structures and new structures. The reference model for existing structures was determined according to the majority geometry and feature and, the average floor height in the region. On the other hand, the reference model for new structures was determined according to TOKI (Housing Development Administration of Turkey). TOKI carries out many residential investment projects throughout the country, especially in urban transformation areas. For this reason, it is considered appropriate to take one of the sample type houses published by TOKI as a reference building. Fig. 2 shows the conditional zone areas and front facades of the representative buildings. Drawings of the reference model for new buildings are obtained from data published on TOKI's website (Housing Development Administration of Turkey, n.d.)

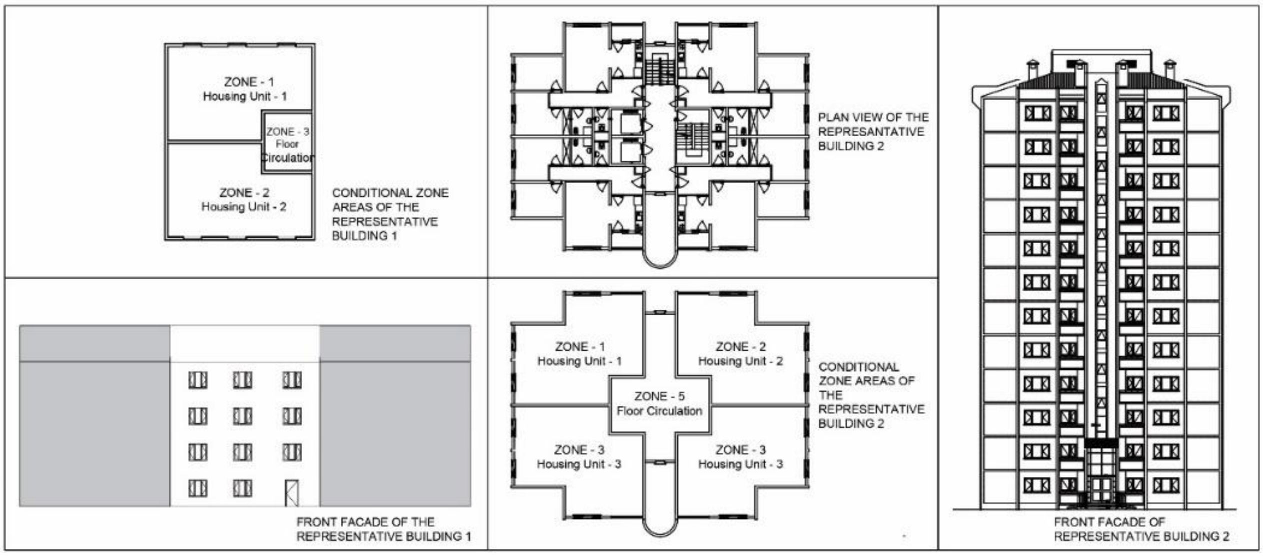

Fig. 2 - Conditional zones, plans and facades of the representative buildings

3.3 Urban Transformation Scenarios

The main objective of determining urban transformation scenarios in terms of energy is to measure the impact of energy to be saved with the urban transformation on energy markets. Also, more than two scenarios created to see the impact on the markets of different energy efficiency scenarios and to measure the adequacy of the regulation in Turkey. As stated above, Gaziosmanpaşa district of Istanbul was selected for these scenarios because of the continuation of a major urban transformation process. With the current situation, three scenarios -showing a decrease in energy demand- are determined as follows.

• S0: The scenario represents the current situation of the model building. The representative building 1 is analyzed as it is, and according to this scenario, energy savings of other scenarios will be determined. Within the scope of urban transformation, S0 indicates that these buildings are constructed with the same energy characteristics in the same geometry.

• S1: The scenarios represent that representative building 2 will be built in compliance with the Turkish standard, which is "Thermal Insulation Requirements for Buildings" (TS825) (Turkish Standards Institution, 2008). Under this scenario, five different sub-scenarios, which are S1A, S1B, S1C, S1D, S1E, created by changing the heat transmission coefficient in the standard, were examined. While the S1A fulfils the minimum requirements of the Turkey standard, building features are improved increasingly in terms of energy savings in S1B, S1C and, S1D. On the other hand, S1E represents a lower energy efficient property than the standard.

• S2: The scenario represents that representative building 1 will be constructed in compliance with the Passive House standard. The heating and cooling energy consumptions are limited to 15 kWh/year with this standard. It is a fact that the geometry of a new passive building, which will be constructed in the scope of urban transformation, will be different. However, in the scenario, representative building 1 is analyzed to make an equivalent comparison with S0.

Table 2 shows the detailed urban transformation scenarios in terms of energy efficiency.

Table 2 - Urban transformation scenarios in terms of energy efficiency

	Construction properties for energy efficiency				**U-values**		
	Ext. Wall	**Roof**	**Windows**	**Other**	**Ext. Wall**	**Roof**	**Windows**
S0	No Insulation	No Insulation	Clear Single Glazing (4mm)		1.429	2.572	4.63
S1A	5cm RW	8cm XPS	Low-E Glass Double (4mm+12mm air+4mm)		0.568	0.380	1.600
S1B	8cm RW	8cm XPS	Low-E Glass Double (4mm+12mm argon+4mm)		0.417	0.380	1.300
S1C	12cm RW	8cm XPS	Low-E Glass Double (4mm+16mm argon+4mm)		0.308	0.380	1.100
S1D	20cm RW	8cm XPS	Low-E Glass Triple (3x4mm+2x12mm argon)		0.202	0.380	0.700
S1E	4cm RW	8cm XPS	Double Glazed Window (4mm+12mm air+4mm)		0.646	0.380	2.616
S2	12cm R.W.	8cm XPS	Low-E Glass Double (4mm+16mm argon+4mm)	Window Shading, Local Building Element Shading, Energy Efficient HVAC	0.568	0.380	1.100

3.4 BIM Based Performance Analysis

In recent years, a lot of energy simulation tools have been developed. However, according to Kim (2013), these tools are complex programs that require time to learn. On the other hand, BIM can combine many different elements such as visualization, spatial data, building geometry data, building envelope characteristics and can make energy estimates.

In our study, Autodesk Revit and, Autodesk Green Building Studio, which is an analysis engine for Revit, will be used to determine the annual energy requirement due to heating and cooling. According to Autodesk, Inc. (2017), the energy model and analysis result can be explored by Revit, but Green Studio can be used for more adjustments and control.

3.5 Life Cycle Cost Approach

The Life Cycle Cost (LCC) is based on the methodological standard in the ISO 15686-5 (ISO, 2008) regulation. According to the regulation, LCC is an important tool to foresee and evaluate the cost performance of structures. The most commonly used methodology as a cost-benefit benchmark in the life cycle approach is the Net Present Value (NPV). NPV can be defined as the difference between the present value of cash inflows and the present value of cash outflows over a period time so, the time value of the money is taken into consideration by NPV. In the scope of the urban transformation, construction of a new building is an initial investment cost. How energy-efficient a building affects both the initial investment cost and the life cycle cost of the structure. It is obvious that as the energy efficiency of the building increases, the investment cost will increase, but, the energy cost will decrease with energy savings in the life cycle. According to this, in the NPV calculations, investment costs, operations and maintenance costs were assumed negative while energy savings were assumed positive, and the calculation is as follows:

$$PV(i,N) = -C_{inv} - \sum_{t=0}^{N} \frac{C_{O\&M,t}}{(1+i)^t} + \sum_{t=0}^{N} \frac{S_g\left(1+i_g\right)^t + S_e(1+i_e)^t}{(1+i)^t}$$

where i is the real discount rate (%), N is the calculation period that shows the time lifespan (years), C_{inv} is the initial construction cost ($), $C_{O\&M,t}$ is the cost of operation and maintenance in t time, S_g is the gas-saving ($), S_e is the electricity-saving ($), and i_g, i_e are real growth rates of gas and electricity prices respectively (%). Whole costs for construction of a building, including all direct and indirect costs, form the initial investment cost. The initial costs will be calculated according to the unit prices published by the Turkey Ministry of Environment and Urbanization. The maintenance and repair costs for S0 are taken as 1% of the investment cost, which is a general approach and is considered to increase by 5 percent every 10 years. Yalçın (2013) states that the maintenance costs of energy-efficient buildings are estimated to decrease by 13% compared to traditional buildings. Accordingly, the maintenance and repair costs of other scenarios were found. Also, energy savings will be calculated for cooling and heating.

According to ISO 15686-5 (ISO, 2008), LCC can include some assumptions. In our study, electricity and natural price growth rates determined as acceptances according to the current situation and trend in Turkey. Energy savings will be found in comparison to the energy spent in the current situation. Due to urban transformation projects are public projects, taxes are neglected in the calculations. For discount rate, LIBOR (London Interbank Offered Rates) data is used, and country risk effect is added. Despite the high inflation rate in Turkey, there has been no increase in energy and natural gas prices for a long time, so electricity price and natural gas price growth rate have taken 0%.

Table 1 - Information for LCC analysis

Data	Values and References
Calculation Period	50 years
Discount Rate	3% (Global-rates.com, 2019)
Electricity Price ($/kWh)	0.45 (Republic of Turkey Energy Market Regulatory Authority, n.d.)
Natural Gas Price ($/kWh)	0.02 (Republic of Turkey Energy Market Regulatory Authority, n.d.)
Electricity Price Growth Rate	0%
Natural Gas Price Growth Rate	0%

3.6 Sensitivity Analysis

The aim is to minimize the uncertainty of the results created by the values used as input in the LCC with the sensitivity analysis. For this reason, input values which have the most effect on the results were analyzed by giving different values. These effects are considered as the life span of the building, discount rate and electricity and natural gas growth rates. As the life of the building increases, energy savings will be higher, and the net present value will decrease as the lifespan becomes shorter. As the life of the building increases, energy savings will be higher, and the net present value will decrease as the lifespan becomes shorter. Therefore, in the sensitivity analysis, N value will be calculated as 40 years and 60 years. The discount rate is the most important factor in determining the net present value. This rate, due to financial uncertainties in Turkey, will be analyzed by 2% and 5%. Also, electricity price and natural gas price growth rates will take into account as %0 and %1.5.

4. Results

The goal of the study is to find the most cost-effective strategy for urban transformation in Istanbul by taking advantage of the cost life cycle. For this purpose, energy analyses were performed for the representative buildings determined accordingly and calculations were made considering the approximate costs.

4.1 Energy Analysis

In accordance with the concept of urban regeneration, the scenario based on the current situation and the scenarios created for the future were used to analyze different representative buildings. Therefore, annual heating and cooling loads per square meter are used as units (kWh/m2/year). Fig. 3 shows the heating and cooling loads according to the scenario analyses performed.

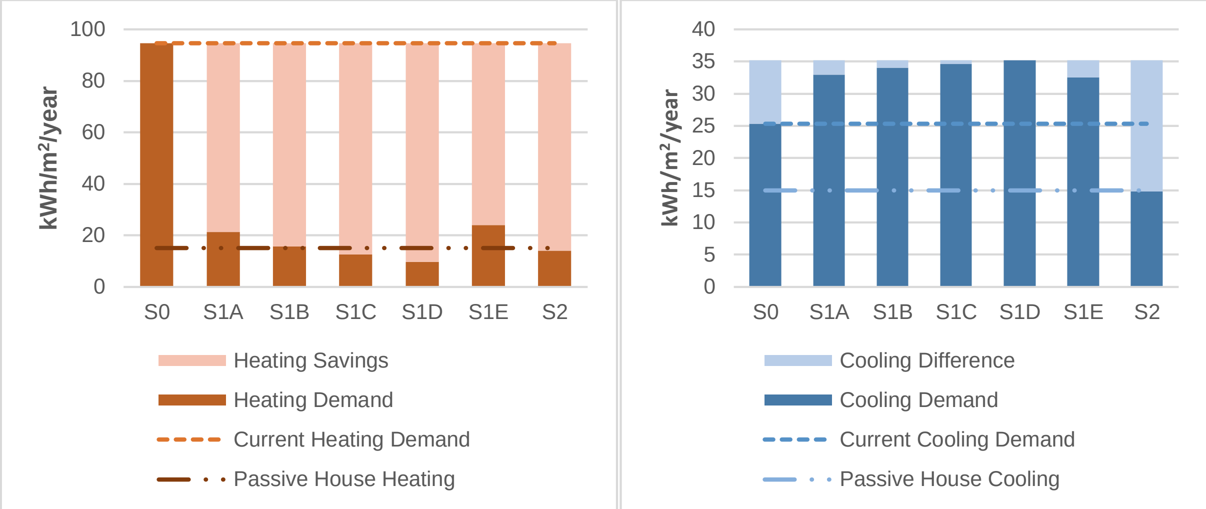

Fig. 3 - The heating and cooling loads according to the scenario-based energy analysis

The reference line at the top of the graphs shows the current heating and cooling demands from the analysis performed in Scenario 0. It is 94.58 kWh/m2/year for heating and, 25.31 kWh/m2/year for cooling. It has been observed that the measures to be taken for energy efficiency in the new buildings will decrease the heating load considerably. The maximum heating energy savings belong to S1D and S1C with 85 and 82 kWh/m2/year, respectively. The maximum cooling energy savings belong to S2 with 10 kWh/m2/year.

4.2 Life Cycle Cost

In the life-cycle cost analysis, considering the investment costs, energy savings and operation and maintenance costs, net present value cost per unit square meter was determined without considering the land price for new buildings in the scope of urban transformation. Since there is a new building cost within the expenditures, it is a natural result that the net present values are negative. Fig.4 illustrates the net present values and savings of the scenarios according to LCC analysis. The most important result here is that the most cost-effective strategy is the S1C, which is a scenario obtained by decreasing the minimum U values determined by the standard. On the other hand, while increasing energy efficiency up to a limited point has a positive effect on life cycle analysis, increasing energy efficiency after a certain point causes the investment cost to increase more as in scenario 1D. Also, the S1E scenario, whose energy characteristics are lower than the minimum specifications of the standard, is less cost-effective than S1A as expected. Another important result is that the S2 scenario, which complies with the passive house standards, is the worst cost-effective strategy based on analyses of standards due to the measures to be taken in order to decrease the high cooling loads. Also, as shown in Fig. 4, although S2 and S1D scenarios provide more energy-saving than the scenario S1C, net present values of both are lower than S1C.

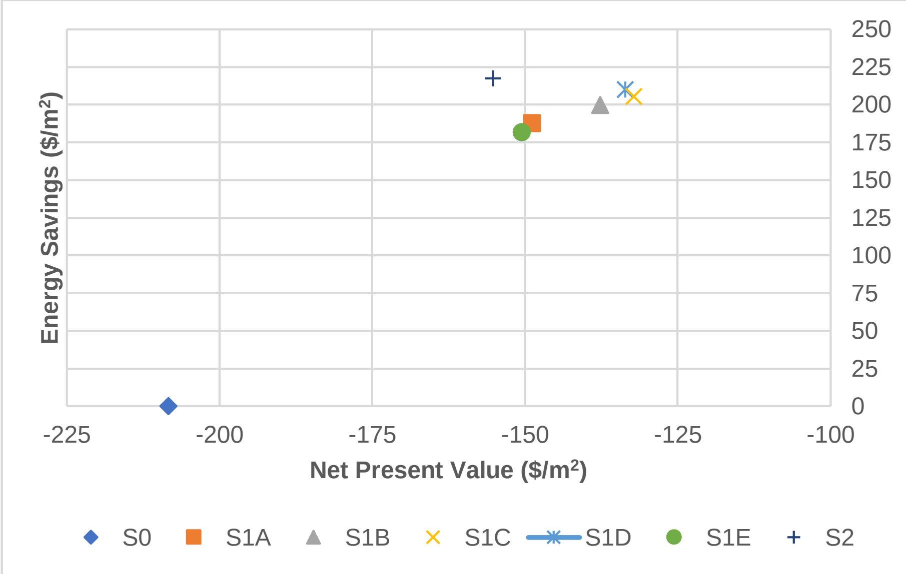

Fig. 4 - The net present values and savings of the scenarios according to LCC analysis

Fig. 5 - Energy-saving net present values

Fig. 5 compares the scenarios of S1A and S1C in terms of energy savings. S1A represents the new building which is in compliance with minimum U values of Turkish standard and, S1C is the most cost-effective scenario obtained by decreasing that U values. Considering the number of housing in Gaziosmanpaşa urban transformation, the average housing square meter, and building life, S1C's current net energy savings is $ 677M$, while the savings of S1A is $ 618M$. In addition, the S1C provides an energy saving of 22 GWh per year and 1,134 GWh for 50 years more than S1A. Taking into consideration the S0 scenario representing the current situation, the energy-saving amount with S1C scenario reaches to 227 GWh in a year and a total of 11.000 GWh in 50 years. The average heating energy in Istanbul is about 70 kWh/m2/year for one building. With the savings in S1C scenario, annual heating energy demands of approximately 30,000 houses in Istanbul could be covered.

4.3 Sensitivity Analysis

The analysis was repeated according to each changed variable input. Table 4 and 5 show the net present value and net present energy savings according to each analysis. According to the sensitivity analysis, a more cost-effective condition occurred as expected with a life span of 40 years, a discount rate of 2% and a 1% increase in electricity and natural gas prices. Also, when electricity and natural gas prices increased by 1%, the most efficient scenarios were reached. In addition, in all cases, S1C stands out as the most cost-effective scenario.

Table 4 - Sensitivity analyses of net present values ($/m2)

Scenario	Base	N=40	N=60	i=2%	i=5%	i_e, i_g= 1%
S0	-208.36	-203.24	-222.41	-218.79	-194.81	-208.36
S1A	-148.93	-161.75	-139.40	-121.04	-185.55	-106.46
S1B	-137.70	-151.85	-127.17	-106.88	-178.15	-92.46
S1C	-132.21	-147.05	-121.17	-99.89	-174.63	-85.69
S1D	-133.63	-148.84	-122.32	-100.52	-177.10	-86.06
S1E	-151.21	-163.74	-141.88	-123.92	-187.03	-110.02
S2	-155.24	-170.66	-143.76	-121.65	-199.32	-106.04

Table 5 - Sensitivity analyses of net present energy savings ($/m2)

Scenario	Base	N=40	N=60	i=2%	i=5%	i_e, i_g= 1%
S0	0	0	0	0	0	0
S1A	187.63	168.56	201.81	229.15	133.12	230.10
S1B	199.83	179.52	214.94	244.05	141.78	245.07
S1C	205.46	184.58	221.00	250.93	145.78	251.98
S1D	210.13	188.77	226.02	256.63	149.09	257.70
S1E	181.95	163.45	195.71	222.21	129.10	223.14
S2	217.32	195.24	233.76	265.42	154.20	266.53

5. Conclusion

As can be seen from the results, the urban transformation project to be carried out in the Gaziosmanpaşa region has great potential for energy savings. It is a natural result that net present values are negative because investment cost includes new construction cost. Since more than one representative building is analyzed, new construction costs should be included in the net present value analysis in order to make an equal comparison. Since the study examined the buildings to be constructed within the scope of urban transformation, the use of two different types of representative buildings was also deemed appropriate for demonstrating the change of the region. In addition, demolition of buildings is a necessary process due to natural disasters as mentioned. Therefore, net present values obtained as a result of the analysis should be considered as a way of showing the most efficient alternative.

Also, this study proves that with the digitalization of the construction industry, it can be created more sustainable and cost-effective cities. One of the most used areas of BIM in construction processes is the design. It is clear that shaping the design and energy efficiency of the buildings with an easy energy analysis with BIM during the design phase will be very efficient in terms of life cycle cost.

When compared with the current situation, it is possible to save energy up to 227 GWh in a year and 11.000 GWh in 50 years with the most efficient scenario to be realized. In addition, it is possible to reach savings in 50 years that equal to 677 M$ net present value. Another important conclusion is that the most efficient scenario with improved energy properties provides more energy savings compared to the scenario, which represents the new building that is in compliance with the minimum U values of Turkish standard. This situation shows that the values of the Turkish standards can be improved or, new strategies can be created in terms of energy efficiency for urban transformation areas according to the region specified analyses.

This study aims to enable a sustainable strategy in the areas of urban transformation. It is a natural outcome that net present values are negative because they include construction costs. Nevertheless, the renewal of buildings in urban transformation in Turkey is compulsory in terms of natural disasters. Therefore, it is of great importance to create the most efficient strategy for new building constructions that are already mandatory.

The study differs from others by considering the potentials created by city transformations. For this reason, it is a pioneer in terms of reflecting the differences in building and settlement typology before and after the urban transformation as in reality with two reference building types. The research can play a huge role in guiding the urban transformation movement for developing countries. Also, using BIM in the design stages of the buildings show that the digitalization of the construction produces a great impact on the purpose of more sustainable cities.

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