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THE LIFECYCLE COST AND CO_2 EMISSION ANALYSIS WITH THE BUILDING INFORMATION MODELING APPLICATIONS

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Original Scientific Paper

In this study, the impact of the Building Information Modeling (BIM) applications on the energy performance of the buildings has been revealed with an application study upon the lifecycle cost and CO_2 emission values. With this purpose, a comparison has been conducted with the Building Information Modeling applications for the alternative status of the building determined according to the variables such as the current location of the building, orientation, southern facade transparency ratio and the outer wall insulation material and thickness.In this respect; the lifecycle cost being 62810 $ in the current state has been attained as 46574 $ for the formed alternative state. CO_2 emission values attained for the fuel consumption have been respectively 6.2 Mg and 3.3 Mg for the current and alternative states. Consequently; the fact that the energy performances of the buildings could be enhanced using the BIM based programs for an applied building or a building that is at the design stage and the environmental impact to be provided in this way have been concretely revealed.

Keywords: *Building Information Modeling; Energy Analysis; Lifecycle Cost; CO_2 emission*

1 Introduction

Technology and life standards have developed together with the industrialization in 20th century, but natural resource and raw material consumption ratio have shown a rapid increase (Armutlu, 2019; Işın, 2016). Together with the occurrence of this environmental problem, the studies conducted regarding the efficient use of energy have gained significance (Shi, 2017).

It is necessary for the governments to make more effort in the issue of the energy efficiency being one of the most important factors regarding the decrease in the energy-based air pollution and reaching the long-term climate missions (IEA, 2018). The studies to be conducted at the design stages of the buildings have great importance to produce solutions for the efficient use of the energy by the countries. It is possible to save 60% energy for the heating and cooling and approximately 50% energy for the artificial illumination with the use of methods convenient for the efficient use of energy (IEA, 2018). CO_2 emission could also be decreased when the energy efficiency of the buildings are increased.

There are many parameters affecting the energy performance of the building. Taking these parameters into consideration before the commencement of the construction of the building is very important in terms of preventing the problems possible to occur afterwards and being able to save energy. Problems that are not possible to solve afterwards may occur when this issue is not paid attention at the design stage of the building and the different solution methods that could be developed will cause to the loss of time and cost (Harputlugil, 2007).

Building Information Modeling (BIM) is a design approach using smart three-dimensional computer models to form, modify, share and coordinate the information at the design stage. Building energy performance analyses could be conducted with the building information modeling applications today. These analyses provide great facilitate on in the issue of designing energy-efficient buildings (Douglass, 2010; knowledge.autodesk.com/support/revit-products). In the literature, there are many studies conducted regarding the improvement of the energy performances for the current buildings and by taking support from BIM-based programs. Abanda and Byers (2016) have calculated the energy consumption in the Revit program of this building upon a sample building. When the building orientations have been changed, it has been concluded that energy could be saved especially in the electricity and fuel consumption. Savaşkan (2015) has formed different scenarios by modifying the number of rooms, transparency ratio, roofing and thermal insulation material upon a sample house seed model using Autodesk REVIT software. He has conducted a study showing that the buildings with high energy efficiency could be designed upon these scenarios. Leinartas and Stephens (2015) have calculated the cost and energy performances using BEopt and EnergyPlus programs on ten types of sample buildings which were constructed before 1978, were independent and whose outer wall material is brick in

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Chicago. Consequently; they have shown that at least 50% energy saving could be provided with the renovations conducted on the building. In addition; it has also been revealed that the implementation of these energy renovations to all of the house buildings in Chicago region before 1987 will provide the investment opportunity to the region. Kuo et al. (2014) have studied the reliability of the BIM-based energy analysis in the concept design stage of a structure. This study has proven the applicability and reliability of the energy analysis via BIM-based programs by comparing the values regarding the electricity use calculated in the simulation program to the measured real values of the production of the electricity. Sancaktar (2015) has examined the heating performance in the buildings before 2000. He has conducted performance and cost analysis by re-arranging the five-storey two-block building with the enhancements possible to be conducted according to TS 825 standard upon TS 825 calculation program. The improvements performed on the walls and windows have provided 56.8% energy saving. Öktem and Ergen (2017) have aimed to form a guide for the companies to adapt to the building information modeling. Two frames have been prepared for this and the validity and convenience of these frames have been assessed. As a result; an operational building information modeling frame that could be used as a guide by the companies has been formed. Akcatir, Nacar and Yeşilata (2011) have determined the criteria according to which the programs used in the energy load calculations could be assessed. For this, they have examined the usage of EnergyPlus, Design Builder and Hourly Analysis Program (HAP) software items and conducted a sample application study with EnergyPlus software. In conclusion, they have expressed that it has met the reliability of the important software items. Douglass (2010) has examined the usage of energy analysis and simulations with the building information modeling. For this, he has conducted the analysis studies of a house he has modeled with Autodesk Revit with Autodesk Ecotect and DesignBuilder. Consequently; he has observed that some problems are faced in the process of transmitting the building information modeling data to the analysis tools, but all the problems could be solved. Besides; the simulation results attained from Ecotect and DesignBuilder have shown a difference of 15% in the annual heating and cooling energy among the passive solar design strategies in the best and worst condition. In his study, Martin (2013) has conducted a comparative study with the integration of Autodesk Green Building Studio to examine the impacts of a primary school on the energy consumption, lifecycle energy cost and carbon emission with the building information modeling. While performing this, examinations that will reveal the benefits of the sustainable and usage life costs of the buildings via building information modeling have been conducted. As a result of his examinations, he has emphasized the importance of the early inclusion of the energy modeling analyses in the conceptual design of the construction projects. He has also specified that early design energy analysis will provide energy saving provision opportunity with the use of reaching cost decisions, *Green Building Studio* and building information modeling at the beginning of the lifecycle of the building. Le (2014) has introduced Autodesk *Green Building Studio* being a software for the analysis of buildings. This software gives the results of the energy consumption such as water usage and costs, natural ventilation potential, carbon emissions based on a real model, local energy resources and weather condition data. He has conducted his study on a villa of 279 m2 modeled with Revit. As a result, a design suggestion that is sustainable and that has energy efficiency for the future projects. Within the results of his study, he has given place to the fact that *Green Building Studio* is a very strong and useful tool operating under real standards and giving highly reliable results. Flores (2016) has aimed to determine the estimation of the energy usage of a building and the potential design developments to be able to be applied before the construction process with the main lines. For this, he has tried to develop building performance analysis using Revit 2017 in a training building. Consequently; the validity of the used method has been verified by taking the eye-catching results into consideration. Also, he draws the attention to the fact that there are possible practical applications and more research potential on this issue.

The energy and cost saving to be provided with the use of BIM applications have been focused in most of the conducted studies and the attained results have been emphasized to be reliable and correct. Besides; it has been specified that considering BIM applications at the design stage will provide more efficient results in the energy efficient building designs, but the applied buildings will also be ultimately beneficial within the scope of the improvement studies in terms of the energy efficiency. The provided energy savings and CO_2 emissions decreasing depending on this and the gained environmental benefit have been the subject of very few studies.

In this study, the impact of Building Information Modeling (BIM) applications on the improvement of the energy efficiency of an applied building or a building at the design stage has been investigated with an application study. As different from the previously conducted studies and the ones in which BIM has been used, the assessments have been calculated upon the lifecycle cost and the CO_2 emission of the fuel necessary for the heating. In this way, the contribution of BIM applications to the environmental impact as well as the energy and cost saving it provides has been desired to be emphasized. For this purpose, a comparison has been conducted upon the lifecycle cost and CO_2 emission values for the determined alternative state of the house determined according to the current state and the variables of orientation, southern facade transparency ratio and external wall insulation material and thickness with the Building Information Modeling applications. Parameters used in the analysis have been evaluated in relation as using the appropriate value selected for the previous parameter in the analysis for the next one. For example, output value for orientation has been used as an input for the next parameter to be analysed.

2 Material and Method

In this study, three dimensional modelings have been conducted with Autodesk Revit and energy analyses have been attained with Green Building Studio. Also a validation study has been conducted upon HAP program for the purpose of proving the correctness of the conducted analyses. The impacts of the variables on the lifecycle cost and CO_2 emission have been examined and a design has been formed as an alternative to the current building in which three variables with the best energy performance have been used together. The energy analysis of the current house and the energy analysis results of the formed alternative design have been compared to examine the impacts of the formed alternative design on the building energy performance.

2.1 Variables Determined for the Current House Information and Formed Alternative Design

There are kitchen, living room and WC in the ground floor and bedrooms in the first floor of the sample house. The furnishing of the ground floor contacts the soil. All of the northern and southern facades and a part of the eastern facade are connected to the outer environment. Floor plans belonging to the house are shown in Figure 1. Drawing of the floor plans used in the formation of the energy analysis model and the internal and external environment data belonging to the building have been formed in Revit 2017 (Autodest Revit, 2017) program. The building A-A section attained upon the Autodesk Revit 2017 drawing and three dimensional image of the building are shown in Figure 2

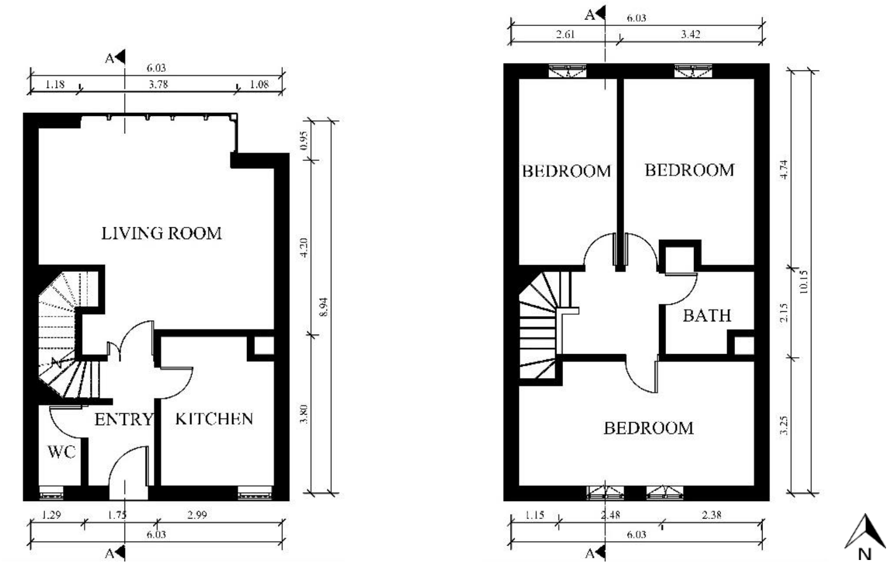
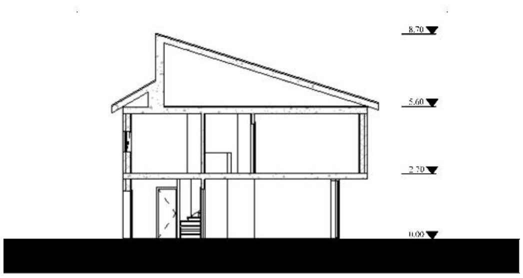
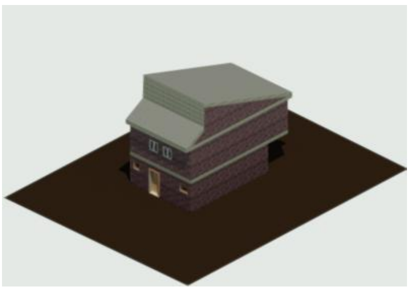


Figure 1. Sketch of the ground and first floors respectively



(a)



(b)

Figure 2. For existing housing (a) A-A section (b) three dimensional image

In Figure 3, the location of the sample house in the adjacent order with the buildings around it is shown. The house has been placed together with the surrounding buildings on the field within eastern-western direction and the front facade of the building has been oriented to north.

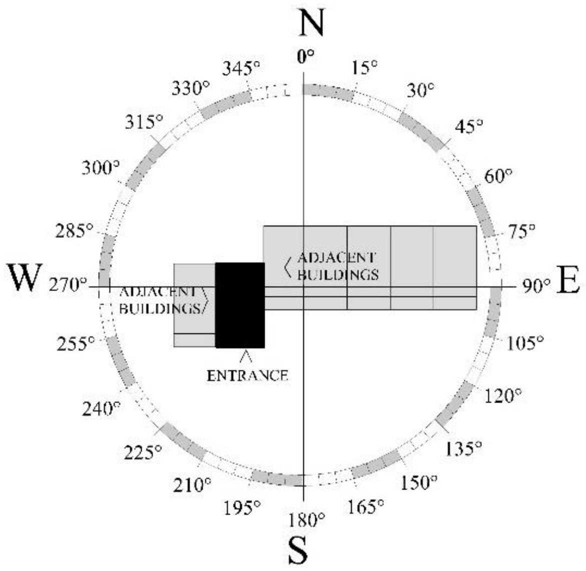


Figure 3. The current location of the building and surrounding buildings

The location of the building selected for the application study has been determined as the city of Elazig with continental climate in 37.67 N latitude and 39.24 E longitude. There are outer environment data used for the simulation in Table 1. The building usage hours by the residents, building usage type and other design data preferred in the program are given in Table 2 for the heating and illumination, U values of the building components are given in Table 3. There is no thermal insulation on the outer walls in the current state. Windows are double-glazed. U value has been accepted as 3.13 W/m^2K and SHGC values have been accepted as 0.76.

The fact that the front facade of the current building has been oriented to north, there is no insulation on the outer walls and the southern facade space is too little have been efficient in the selection of these variables as determinative to form an alternative design for the current state. In this respect; the current state has been accepted as 0º and the orientation has been changed with the increasing angles by 15º in clockwise direction while forming an alternative design for the current building in the study. Analyses also have been conducted for the situations in which XPS, EPS, glass wool and rock wool insulation materials have been applied to the outer walls with the thickness of 3, 5 and 8 cm (Table 4) and the situations in which the southern facade transparency ratio being 6.5% in the current state has been taken as 15, 30, 40, 50, 65, 80%.

Table 1. Climate data for the location

Location	Elazığ, Turkey
Latitude	37.67
Longitude	39.24
Summer Dry Bulb	41˚C
Summer Wet Bulb	17 ˚C
Winter Dry Bulb	-8 ˚C
Mean Daily Range	22 ˚C
Maximum Temperature	43 ˚C
Minimum Temperature	-13 ˚C

Table 2. Building design data

Building Type	Residental Housing
Area	103 m²
Volume	248,75 m³
Number of People	4
Peak Load	August 17.00
Heating System Indoor Comfort Temperature For Heating	Fan Coil System 21,11 ˚C
Cooling System Indoor Comfort Temperature For Heating	Fan Coil System 23,33˚C
Operating Schedule for Heating	00.00-05.00 between %90 06.00 %70 07.00-08.00 between %40 09.00-14.00 between %20 15.00 %30 16.00-18.00 between %50 19.00-20.00 between %70 21.00 %80 22.00-23.00 between %90
Operating Schedule for Lighting	00.00-04.00 between %10 05.00 %30 06.00-09.00 between %45 10.00-17.00 between %30 18.00 %60 19.00-21.00 between %80 22.00 %60 23.00 %30
Calculation Method	ASHRAE thermal balance method

Table 3. U values of the building components

Building Components	**U Values ($W/m^2.K$)**
Roof	2.95
Walls	2.57
Door	2.19
Wındows	3.13
Floor	2.49

Table 4. Thermophysical properties of insulatıon materials used in the study

Insulation Materials	Thermophysical Properties of Insulation Materials		
	Thermal conductivity (W/ m.K)	**Specific heat (J/g.˚C)**	**Density (Kg/m^3)**
XPS	0.027	1.0300	40
EPS	0.035	0.800	20
GLASSWOOL	0.040	1.000	65
ROCKWOOL	0.044	0.9200	110

2.2 Lifecycle Cost Assessment

Lifecycle Cost Assessment (LCCA) is a method for the evaluation of the total cost. It consists of the analyses regarding the environmental impacts of the building. The costs regarding the building consist of;

- First cost in which purchasing and construction costs are included,
- Fuel cost,
- Operation - Maintenance – Repair cost,
- Residue costs stemming from sale or disposal,
- Finance fees such as credit – interest payments,
- Non-monetary benefits and costs.

It is aimed to determine, measure and express in currency the economic impacts with the lifecycle analyses. The other aim of the analyses is to estimate the total cost of the design alternatives and determine the design that is qualified, functioning, consistent and with the lowest cost for the construction.

Lifecycle cost analyses is an important element of the studies conducted on determining which design ideas have more economic income in the building performance analyses. In this study, only the lifecycle usage and cost analyses of the energy consumption stemming from the need for cooling energy and the fuel consumption stemming from the need for electricity and heating energy and hot water have been conducted (Röck et al., 2018; Bueno and Fabricio, 2018; Soust-Verdaguer et al., 2018).

2.3 CO_2 Emission

Carbon dioxide (CO_2), methane (CH_4), diazotemonoxide (N_2O) and F-gases causing to global warming by preventing the back reflection of the sun rays causing to greenhouse effect from the earth surface and the gases of nitrous oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and sulphur dioxide (SO_2) being indirect greenhouse gases cause to the greenhouse gas emissions (Tuik, 2018).

Figure 4 shows the emission amounts of CO_2, SO_2, NO_X, CO, C_XH_X and particles emitted to the environment before and after the insulation of a building. According to the graphics, CO_2 emissions form 99.4% of the emissions being the majority.

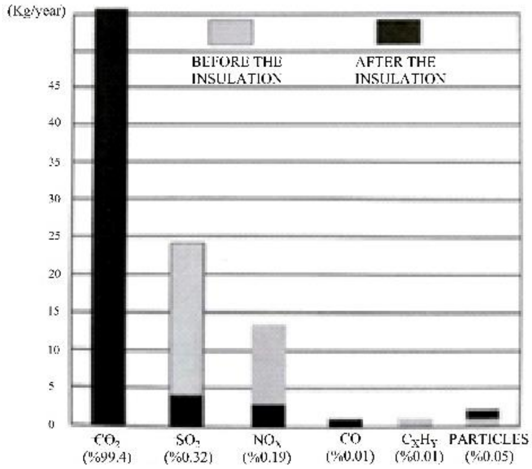


Figure 4. Isolated and uninsulated emissions of the same buildings (Karakoç et al.,2011).

2.4 Validation Study

Heating and cooling load have been calculated upon HAP (Hourly Analysis Program) 4.90 used in the heating and cooling load calculations for the purpose of ensuring the correctness of the results attained from Autodesk Revit 2017 program. Validation study has been conducted upon the house sample to be used for the study. The results attained for Revit under the same internal and external environmental conditions have been compared with this calculation.

The heating and cooling load analyses and the total loads of roof, outer wall, outer door and window being four components having the highest impact on the heating and cooling load of the building are given in Table 5. Cooling load has been calculated as 2969 W for HAP and as 2894 W for REVIT. Heating load has been calculated as 9131 W for HAP and as 9736 W for REVIT. The fact that the difference between cooling loads has been calculated as 3% and the difference between the heating loads has been calculated as 7% show that the results are within close values and the analyses conducted with Revit could be counted as valid.

Table 5. Comparison of REVIT and HAP results

	REVIT(W)	**HAP(W)**
Heating Load	9736 W	9131 W
Difference	%7	
Cooling Load	2894 W	2969 W
Difference	%3	

3 Results and Discussion

Analyses have been conducted for the current state of the building at the first stage of the study. The lifecycle energy cost of the building for the sample house, annual energy cost, lifecycle fuel usage, annual fuel consumption amount and energy usage intensity are given in Table 6.

In this respect; the lifecycle cost showing the fuel and electricity consumption cost has been attained as 62818 $ and the CO_2 emission stemming from the fuel has been attained as 6.2 Mg.

Table 6. Energy analysis data for sample housing

Lifecycle Cost ($)	62818
Annual Energy Cost ($)	4611
Lifecylce Fuel Consumption (MJ)	3751404
Annual Fuel Consumption (MJ)	125047
Energy Usage Intensity (MJ / m² / year)	1671
Annual CO_2 Emmission (Mg)	6.2

3.1 Findings Attained with the Modification of Building Orientation

Lifecycle cost according to the energy usage for the situations in which the building orientation has changed with the increasing angles of 15º, the fuel usage amount during the lifecycle and the CO_2 emission amounts according to the fuel usage are given in Table 7.

The impact of the orientation on lifecycle is more than its impact on the energy usage. The highest lifecycle cost is 65590 $ with +285º and the lowest cost is 62560 $ with +30˚ orientation. CO_2 emission amount changes depending on the different orientation angles between 6 and 6.3 Mg.

When the energy and fuel consumption amounts are examined depending on the building orientations, the orientation with the lowest energy consumption is orientation +30˚ with 4594 $ (Figure 5) and the difference between +195˚ orientation and +30˚ orientation whose lifecycle costs are very close to each other is 11$. It is seen that the orientation with the lowest fuel consumption is +195˚ orientation with 2376$ (Figure 6). 195˚ - 240˚ orientations in which the CO_2 values calculated according to the fuel consumption are low decrease the harmful gas emission given by the building to the environment when compared to other orientations with 6.0 Mg.

Orientation of the living spaces in which users spend more time during the day to benefit from the daylight more to the southern facade will make the house more functional. In the current state, orientation of kitchen which is in the southern facade to the north will increase the efficiency of the building.

When the results related to the building orientation are taken into consideration, the most ideal orientation among all the values has been selected as +195˚ both for the cost and energy usage according to their impact on the building energy performance and presented in Figure 7.

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Table 7. Lifecycle and the CO_2 emission amounts for building orientation

Building Orientation	Lifecycle Cost ($)	Lifecycle Fuel Consumption (MJ)	Annual CO_2 Emission (Mg)
0˚	62810	3751407	6.2
+15˚	62568	3733746	6.2
+30˚	**62560**	3728328	6.2
+45˚	62680	3735108	6.2
+60˚	62921	3743382	6.2
+75˚	63946	3754944	6.2
+90˚	64533	3758691	6.2
+105˚	64656	3747276	6.2
+120˚	64558	3731106	6.2
+135˚	64321	3710220	6.2
+150˚	63788	3695967	6.1
+165˚	63345	3676389	6.1
+180˚	62607	3659046	6.1
+195˚	**62571**	**3633732**	**6.0**
+210˚	62791	3614571	6.0
+225˚	63595	**3613953**	6.0
+240˚	64580	3633108	6.0
+255˚	64956	3666423	6.1
+270˚	65423	3708213	6.2
+285˚	65590	3750399	6.2
+300˚	65322	3786414	6.3
+315˚	64830	3804591	6.3
+330˚	64005	3798576	6.3
+345˚	63056	3774273	6.3

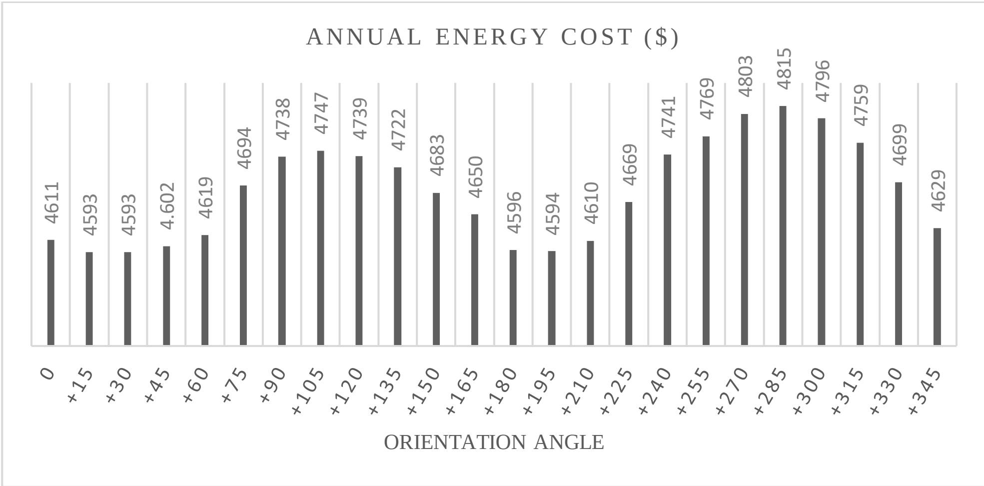

Figure 5. Annual energy cost graph with building orientations

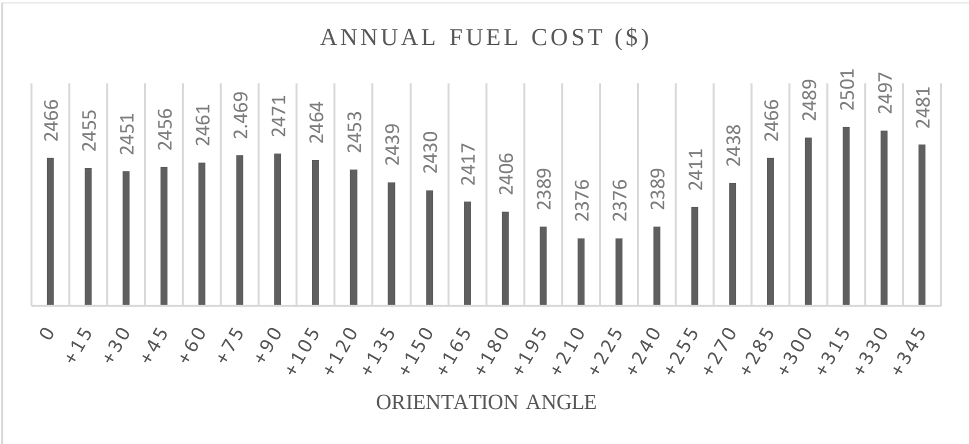

Figure 6. Annual fuel cost graph with building orientations

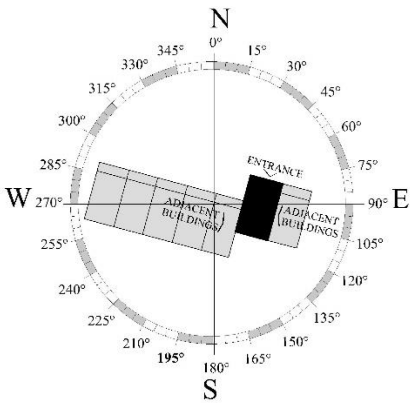

Figure 7. Recommended for building orientation 195˚

3.2 Findings Attained with the Change in the Southern Facade Transparency Ratio

Eastern and western facades do not affect the building transparency ratios because the sample house is in adjacent order with other houses in its surroundings. Energy usage ratio will increase because the increase in the facade transparency ratio in the northern facade will increase the fuel usage. Because the modification of the transparency ratio in northern facade will not increase the energy efficiency, the current state has not been changed in the northern facade transparency ratio.

What affects the energy efficiency of the building most is the southern facade transparency ratio. For this, the energy consumptions of the southern facade within the transparency ratios of 15, 30, 40, 50, 65, 80% have been examined.

Figure 8 and Figure 9 presents the annual energy and fuel costs respectively. While the energy cost increases together with the increase in the southern facade transparency ratio, fuel usage amount decreases. Annual energy cost increase becomes 80$ while the facade transparency ratio passes to 30% from 15% and from 30% to 40% and this difference changes between 100-280 in other transitions. Energy usage intensity and annual fuel usage amount belonging to the change in the southern facade transparency ratio are given in Table 8, lifecycle analysis and CO_2 emission amounts are given in Table 9. Energy usage intensity has decreased approximately by 0.015 MJ/m^2/year between 15% and 30%, but it has started to increase again when the transparency ratio has been increased from 40% to 50%. The increase in the southern facade transparency ratio in Table 9 has caused to the increase in the lifecycle cost stemming from the energy usage. The increase in the southern facade transparency ratio has caused to the decrease in the lifecycle fuel usage amount stemming from the fuel usage of the building and the CO_2 emission stemming from the fuel usage. This situation has occurred due to the calculation of the unit price of the electricity on 0.17 $ and the calculation of the unit price of the fuel costs on 0.02 $. Annual fuel consumption has continuously decreased together with the increase in the southern transparency ratio. When the energy usage intensity is taken into consideration, the determination of the southern facade transparency ratio as 40% will provide advantages in energy efficient building design.

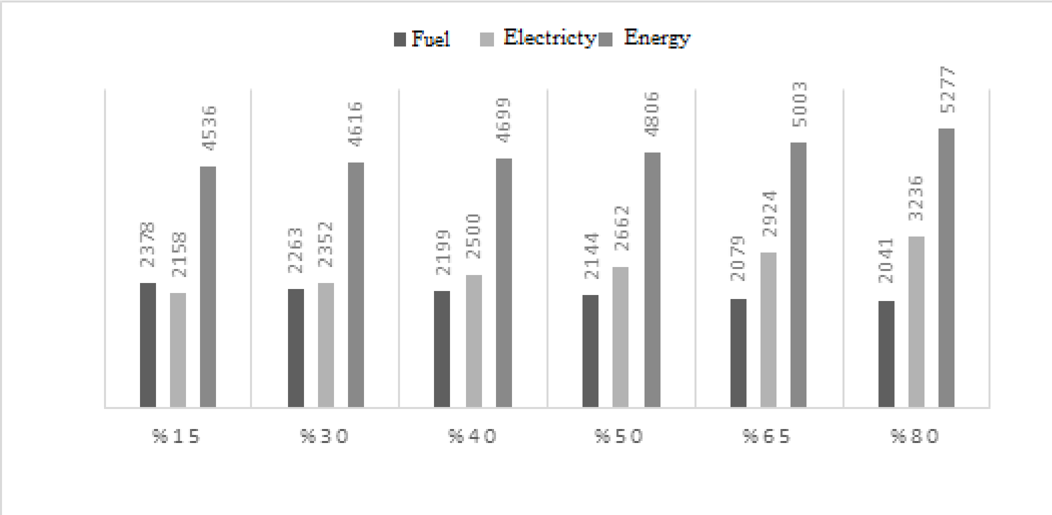

Figure 8. Annual energy cost for changing facade transparency

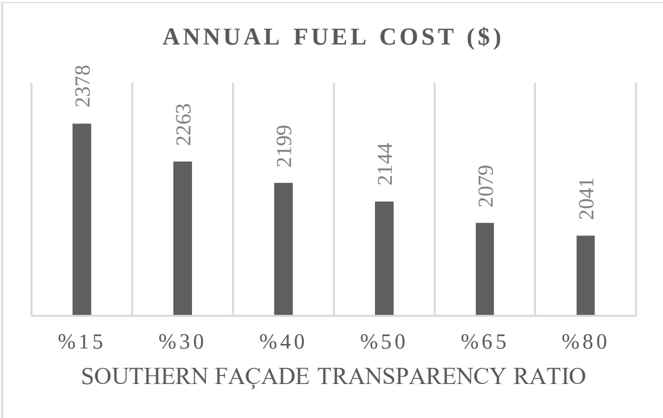

Figure 9. Annual fuel cost for changing facade transparency

Table 8. Annual energy and fuel use according to the transparency rate of the southern facade

Transparency Ratio	Annual Energy Cost ($)	Energy Usage Intensity (MJ /m^2/year)	Annual Fuel Consumption (MJ)
%15	4536	16299	120541
%30	4616	16148	114755
%40	**4699**	**16144**	**111488**
%50	4806	16217	108708
%65	5003	16452	105415
%80	5277	16925	103464

Table 9. Life cycle analysis and CO2 emissions for southern facade transparency

Transparency Ratio	Lifecycle Cost ($)	Lifecycle Fuel Consumption (MJ)	Annual CO_2 Emission (Mg)
%15	61783	3616224	6.0
%30	62871	3442641	5.7
%40	64006	3344643	5.6
%50	65463	3261240	5.4
%65	68143	3162462	5.3
%80	71873	3103911	**5.2**

Within the direction of the information belonging to the southern facade transparency ratio, the option that will provide benefit from the sunlight and will affect the energy load of the building least becomes 40% southern facade transparency ratio.

3.3 Findings Attained with the Change in Thermal Insulation Material

Thermal insulation material has not been applied to the current state of the building. The external wall section for the current building is shown in Figure 10. Non-insulated external wall layers consist of 9 cm brick, 25 cm reinforced concrete curtain wall and interior rendering from the outside towards the inside. Insulation materials have been separately added to the non-insulated external wall according to their thermal values. Lifecycle cost, annual energy cost, energy usage and annual fuel usage amount for the different insulation materials of the building are given in Table 10. Energy cost, energy usage intensity and fuel usage values show parallelism with one another for the insulation materials. Energy and fuel usage are ordered from the highest to the lowest as the rock wool, glass wool, EPS and XPS.

It is seen that the energy and fuel usage difference between 3 cm and 5 cm thicknesses of the insulation materials is higher. When the thicknesses of the insulation materials are raised to 8 cm, a decrease at a less ratio occurs for the fuel and energy usages. Energy cost difference between 3 cm and 5 cm thicknesses becomes 135$ and the difference between the energy usage intensities becomes 69.2MJ/m^2/year for XPS which is the insulation material with the lowest values of annual energy and fuel usages. The energy cost difference between 8 cm and 5 cm becomes 186$ and the difference between energy usage intensities becomes 34.7MJ/m^2/year. These differences show that increasing the XPS thickness to 8 cm decreases the energy amount per m^2 in a less ratio.

Figure 11 shows the impact of the insulation material on the annual energy cost. Annual energy costs of rock wool and glass wool are closer to each other, but high when compared to EPS and XPS.

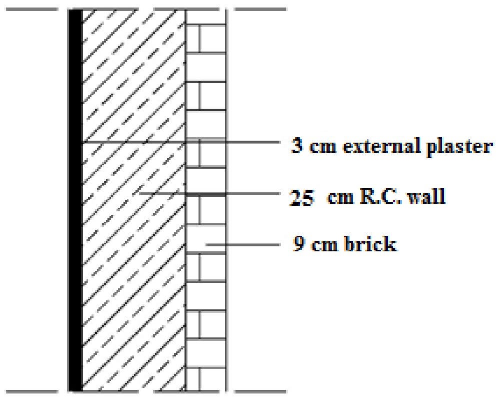

Figure 10. External wall section for existing building

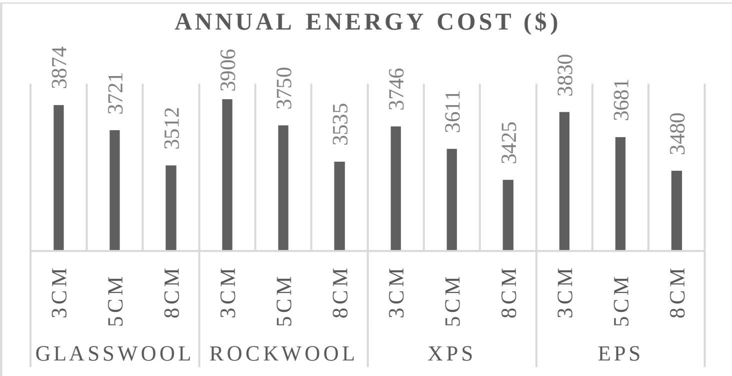

Figure 11. Annual energy cost for different insulation materials

Table 10. Annual energy and fuel usage according to insulation material

Insulation Material	Thickness of Insulation Material	Annual Energy Cost ($)	Energy Usage Intensity (MJ /m²/year)	Annual Fuel Consumption (MJ)
GLASSWOOL	3cm	$3874	1335.3	93840
	5cm	$3721	1257.9	86555
	8cm	$3512	1214.3	79268
ROCKWOOL	3cm	$3906	1350.0	95291
	5cm	$3750	1271.4	87879
	8cm	$3535	1225.6	80376
XPS	3cm	$3746	1276.4	88037
	5cm	$3611	1207.2	81506
	8cm	**$3425**	**1172.5**	**75246**
EPS	3cm	$3830	1315.0	91847
	5cm	$3681	1239.7	84744
	8cm	$3480	1199.0	77804

Annual fuel usage cost graphics for the insulation material is given in Figure 12. The insulation material with the lowest annual fuel cost is 8 cm XPS and the closest value becomes 8 cm EPS. The costs of rock wool and glass wool at 5 and 8 cm thicknesses have gradually come closer to each other.

Lifecycle cost, fuel amount used during the lifecycle and CO_2 emission amount stemming from the fuel usage are given in Table 11 according to the energy usage of the different insulation materials. The most advantageous insulation material in terms of the energy usage is XPS and the results attained for EPS show that it is close to XPS. When the energy usage amounts of the insulation materials are examined according to their heat conductivity, specific heat and intensity values, it is seen that the most convenient insulation material is 8 cm XPS for the sample house.

Table 11. Life cycle analysis and CO_2 emissions for insulating material

Insulation Material	Thickness Of Insulation Material (cm)	Lifecycle Cost ($)	Lifecycle Fuel Consumption (MJ)	Annual CO_2 Emission (Mg)
GLASSWOOL	3	$52767	2815209	4.7
	5	$50682	2596660	4.3
	8	$47836	2378032	4.0
ROCKWOOL	3	$53203	2858741	4.8
	5	$51084	2636374	4.4
	8	$48149	2411293	4.0
XPS	3	$51031	2641121	4.4
	5	$49191	2445183	4.1
	8	**$46648**	**2257388**	**3.8**
EPS	3	$52169	2755396	4.6
	5	$50143	2542322	4.2
	8	$47401	2334112	3.9

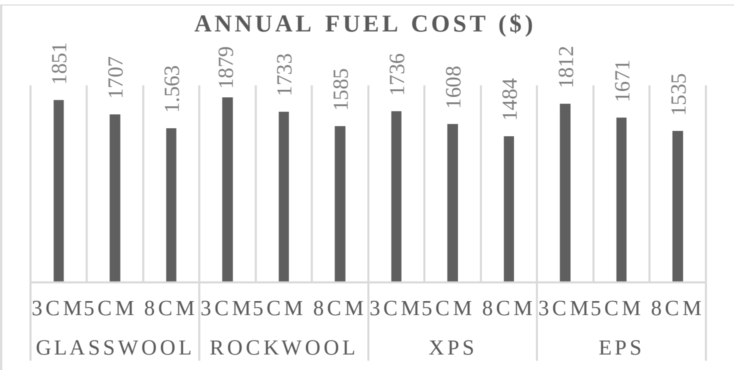

Figure 12. Annual fuel cost for different insulation materials

3.4 Comparison of the Suggestion Improving the Building Performance and the Current State

The selected alternative design, current location and the annual energy cost graphics of the selected parameters are given in Figure 13. The fact that the difference between the annual energy costs for the current house and the formed alternative is 1191$ shows the advantage that could be provided in terms of cost.

The graphics in which the alternative design, current location and the selected parameters are compared according to their annual fuel costs is given in Figure 14. The parameter being most efficient in decreasing the fuel costs of the alternative design has been 8 cm XPS insulation application.

The selected alternative design, current location, the lifecycle assessment of the selected parameters and CO_2 emission amounts are given in Table 12. Lifecycle cost of the current house is 62810$ and this cost decreases to 46648$ in the formed alternative. It also shows decrease in the selected parameters and in the formed alternative in the amount of the annual CO_2 emission amount stemming from the fuel usage.

The highest impact has been attained with the change in the thermal insulation material of the outer wall in the changed parameters. While the energy usage cost of the house is 4611$ in current situation, it becomes 3425$ when 8 cm XPS insulation material is used. Decrease has been observed in the energy usage, lifecycle cost and CO_2 emission amount stemming from the fuel usage in the alternative design formed by using the optimum energy usage values of the parameters of building orientation, southern facade transparency ratio and outer wall thermal insulation material. The lifecycle cost being 16236$ in the formed alternative design decreases the CO_2 emission amount by 2.9 Mg.

While the annual energy cost of the house is 4611$ in the current state, it has been decreased to 3420$ in the formed alternative. Annual fuel cost has decreased from 2466$ to 1302$, annual heating cost per square meter has decreased from 22.87$ to 9.92$, lifecycle cost has decreased from 62810$ to 46574$, annual CO_2 emission for on-site fuel usage has decreased from 6.2 Mg to 3.3 Mg. while the fuel usage cost for heating forms 51% of the total energy cost in the current situation, 32% of the total energy is fuel cost in the alternative design. The energy consumption amount used for heating has been attained as 66% at the first situation and has been attained as 47% for the formed alternative.

Table 12. Lifecycle analysis and CO2 emissions

Affected Parameter	Lifecycle Cost ($)	Lifecycle Fuel Consumption (MJ)	Annual CO_2 Emission (Mg)
Existing housing	62810	3751407	6.2 Mg
+195° orientation	62571	3633732	6.0 Mg
%40 Transparency ratio	64006	3344643	5.6 Mg
8cm'lik XPS insulation	46648	2257388	3.8 Mg
Alternative result	46574	1980352	3.3 Mg

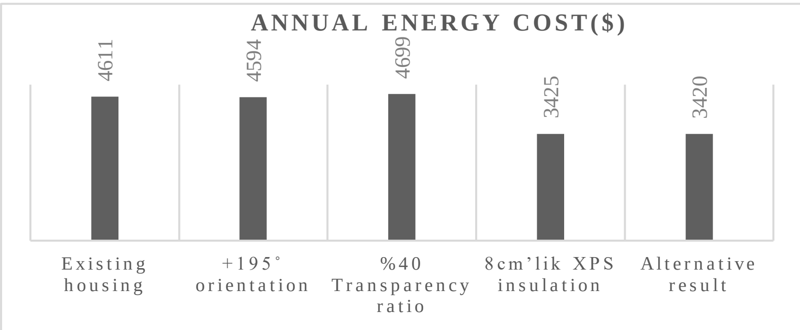

Figure 13. Annual energy cost for selected alternative design

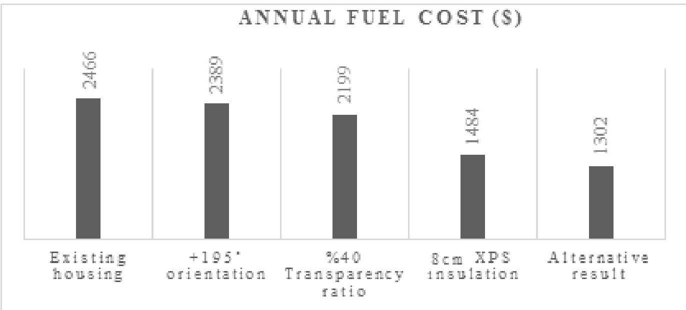

Figure 14. Annual fuel cost for selected alternative design

4 Conclusion

This study has been prepared with the integration of Autodesk Revit 2017 software with Green Building Studio. In the study, the impacts of the variables belonging to building orientation, transparency ratio and external wall thermal insulation material being from the parameters affecting the building energy performance on a used sample has been examined with BIM and an alternative design has been formed by taking the attained analysis results into consideration. The energy and cost savings of the formed alternative design and current building have been comparatively presented. Moreover; the lifecycle assessments and CO_2 emissions of the buildings have been mentioned and it has been aimed to form a foresight regarding these issues.

The results obtained from the study could be sequenced as follows;

- The highest impact in the changed parameters has been attained with the change in the thermal insulation material of the external wall. While the energy usage cost of the house in the current situation is 4611$, it becomes 3425$ when 8 cm XPS insulation material is used.
- Decrease has been observed in the energy usage, cost, usage amount during lifecycle and CO_2 emission amount stemming from the fuel usage in the alternative design formed by using the values of the parameters of building orientation, southern facade transparency ratio and outer wall thermal insulation material with the optimum energy usage.
- While the annual energy cost is 4611 $ in the current state of the house, it has decreased to 3420 $ in the formed alternative.
- While the annual fuel cost of the current house is 4611 $, it has decreased to 1302 $ in the formed alternative.
- Annual heating cost per square meter could be decreased from 22.87 $ to 9.92 $.
- Lifecycle cost has decreased from 62810 $ to 46574 $.
- Annual CO_2 emission for on-site fuel usage has decreased from 6.2 Mg to 3.3 Mg.
- While the fuel usage cost for heating in current situation forms 51% of the total energy cost, 32% of the total energy is fuel cost in the alternative design.
- While the energy consumption amount used for heating has been 66% in the first situation it has been attained as 47% for the formed alternative design.
- In the formed alternative design, lifecycle cost decreases by 16236 $ and CO_2 emission amount decreases by 2.9 Mg.

The results of the study on the improvement of the energy performance have affected the fuel usage more than electricity usage. Despite this; due to the fact that the fuel costs have been calculated upon 0.02$ and the electricity costs have been calculated upon 0.17$, decreasing the usage of electricity will decrease the energy consumption cost more. With this study, it has been shown that it is possible to conduct the energy analyses for a building applied or at design stage with the building information modeling applications and the validity of these analyses will also be able to be provided.

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