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A STUDY FOR DETERMINATION OF COSTS AND DESIGN OPTIMIZATION OF REINFORCED CONCRETE DUPLEX VILLA STRUCTURES

Keywords: building cost, functional element method (FEM), regression analysis (RA), villa, building

Abstract

In this study, it is aimed to estimate the cost of building by Functional Element Method and to determine the optimum building dimensions for minimum costs. For this purpose, construction costs of similar two-storey villa projects with reinforced concrete system were calculated and Regression Analysis was performed by utilizing the available data. "Building heights of these structures, basement floor areas, 1st floor areas, exterior areas, exterior section spaces, bathroom numbers, number of wc, kitchen numbers, total wet section areas, number of balconies, room numbers and hall numbers" are the main criteria in modeling. They were taken as functional evaluation criteria. The cost calculations of the Regression Analysis were compared with the actual costs of the villas and the performance of the model was evaluated. According to the study, the data obtained from the Regression Analysis calculations generated gave applicable results.

1. Introduction

Analysis of a construction project in terms of cost, time and quality is the most important problem encountered in planning. In the preliminary estimation stage where the investment decision will be taken, the amount of resources required for the investment and the project cost at the end, the estimator has no drawings with high level of detail. The only information to be used is the data obtained from previous projects. Considering the intense competition environment in which the construction industry is involved, it is clear that there is a need for fast and efficient methods that can be used by the technical staff involved in planning and cost control. Various cost models have been developed as a result of researches in order to determine the effects of decision-makers on the cost and to plan and control the costs by taking into consideration the construction methods, timing of construction works and various characteristics of the building. With the help of the model to be used, factors such as material, time, production process which affect cost and cost can be controlled. A cost model that provides effective cost control needs to have some features. Such a model; should be suitable for the process or processes to be used. The information to be entered into the model must be accurate and at a certain level, this information should be entered in time and kept up-to-date so as not to be affected by the time factor. The model should be available to all groups (employer, construction company, subcontractor, etc.) [1].

Cost; It is defined as the sum of the spent values until a product is obtained in production. Construction costs are the sum of the items produced by multiplying the production quantity and the price determined for that production. No matter how long the construction period is, the amount of the products to be constructed in a construction will not change; It is also possible to calculate the cost of construction prospectively by calculating the prices of the productions prospectively. While constructing a building in the construction sector is more in the process of idea, it is of great importance in terms of establishing the financial model correctly, eliminating cash flow problems and preventing national wealth losses. This will be possible by making the cost estimation correctly [2].

Costs in construction; they are also affected by the special conditions of the raw material used. The demands of customers, the limitations of the state and local administrations, the environmental conditions and the aesthetic appearance are important factors in the creation of architectural projects. Furthermore, the construction site, the structure of the floor and the technology to be used can cause different costs even in construction with the same shape [3].

One of the issues to be considered for any building project is the size of the building. This is an important factor in spending. Because expenditures are not proportional to changes in size. Larger structures have lower unit costs than smaller scale projects. Smaller factories cause more cost per unit than larger ones. This is, to some extent, relevant to the theory of scale economics. Planning small projects takes more time per unit, which is reflected in plan expenditures. Large projects can be managed more effectively, and this can be completed in a shorter time. The form of any building plan has a significant impact on the total cost of the project. This effect is not limited to mere external costs. Depending on the theory, which is largely known as the wall-to-ground ratio, a square-planned structure will provide the most economical solution in many cases. A square form will result in fewer walls in the total ground area. The more complex the form, the higher the cost will be based on the required floor space. The reason why an irregularly shaped plan is more costly can be attributed to the number of corners. This is known as a factor affecting brick and roof costs. [4]

The cost-based cost calculation is a type of cost calculation used in the design phase of the building production process for cost planning and control. In this method, building functions are measured by means of the preliminary project, and then the unit price is determined for each element and the unit price is multiplied by the unit cost and the functional cost of the element is found. The costs of the functional elements are summed and the total building cost is calculated. The biggest challenge in the element-based cost calculation is the categorization of the normal scale of the structure into categories for cost analysis. That is, the functional element can be subdivided into sub-functions depending on the development of the design, and the sub-functions to the construction units having components. As soon as the first alternative solution arises in relation to design, preparing a preliminary cost plan is necessary to see whether the solution remains within the previously defined cost limits. However, at this stage, the number of elements that can be measured over the schematic drawings is very small. Therefore a very short list of elements is required. Each of the identified elements is compared with the equivalent elements of the structure taken as an example in the preliminary estimation stage, and is calculated by taking into account the price increases. The results show the first preliminary cost plan. After the preliminary cost plan is finalized, the cost analysis of the sample structure is utilized for a more detailed cost plan depending on the information obtained from the design. The amount of elements for the elementary cost of the project is measured on the drawings of the project being designed. The calculation can be done in two ways: by unit costs of the elements and by way of proportioning; In the calculation of the unit costs of the elements, the total cost of the element is obtained by multiplying the element by the square meter cost obtained from the analyzes. The amount found is divided by the floor area, which is the cost per square meter floor area of the element. When the ratio method is used, the ratio of the total area of the project being projected and any element of the sample project to the floor area is calculated, and the figures obtained from the two projects are multiplied by the cost of the element per square meter floor area. The result is multiplied by the total floor area and the total cost is obtained. There are two reasons why the total finances of the elements are expressed per square meter floor area: first, it is possible to make an appropriate comparison with the other structures. The second is that it is not possible to understand if there is any loss or gain, when only unit prices are considered. It may be possible to see how the selection of any element will affect the cost of the square meter of the building, but by calculating the cost per square meter of the element. If the specified cost base is exceeded, the accounts are reviewed and determined by which element this increase occurs. By returning to the redesign, the calculations are repeated in line with the changes made and a new cost plan is prepared. As the design evolves, the building elements are also divided into the sub-elements that form themselves. Naturally, the most detailed cost calculation based on the elements is made in the application project [5].

A model for estimating the cost of building with functional element method was able to estimate the costs of multi-storey housing structures with 32% error [6]. Evidence and Uğur have created an artificial neural network based cost estimation model for multi-storey reinforced concrete housing buildings. The model can make available cost estimates with low error rates (5.7%) [7]. Uğur et al. Used artificial neural networks (ysa) in estimating the cost of masonry housing [8]. Uğur has done a study on the optimum dimensions for reinforced concrete multi-storey apartment buildings to be constructed at minimum cost [9].Although there are not many Polish-language publications concerned with the issues of project finance there are many other exhaustive resources on this method. The definition of this form of investment financing is given for example by P.K. Nevit and F. Fabozzi, who define it as “a financing of a particular economic unit in which a lender is satisfied to look initially to the cash flow and earnings of that economic unit as the source of funds from which a loan will be repaid and to the assets of the economic unit as collateral for the loan"[1]. J.D. Finnerty stresses that "the providers of the funds look primarily to the cash flow from the project as the source of funds to service their loans and provide the return of and a return on their equity invested in the project"[2].

2. Purpose and Method

In this study, it has been tried to develop a practical model which can be used to calculate the construction costs of two storey reinforced concrete villa projects. To do this, it was created a Regression equation by using a large number of samples. The data set was formed by subtracting the quantities and the inventions of 111 similar buildings. Modeling; building heights, basement floor areas, 1st floor areas, exterior areas, exterior section spaces, bathroom numbers, number of wc, kitchen numbers, total wet space areas, number of balconies, number of rooms and number of saloons; the main functional evaluation criteria. The model was also tested with data on 7 structures for control. In addition, graphs indicating the effect of the change of these criteria on the changes in average (m^2) costs have been formed.

3. Application

The effect of all parameters on the building cost and the formula formulated by the linear regression analysis are as follows;

Y = -238008,882 + 146,712 Xa + 1097,478 Xb + 496,827 Xc + 22973,807 Xd + 122,749 Xe + 181,207 Xf – 7466,62 Xg + 2995,767 Xh – 30215,280 Xi + 399,628 Xj + 7157,634 Xk + 3853,733 Xl + 24591,337 Xm = Building Cost (1)

In this equation;

a: Basement floor area number	g: bathroom number
	h: wc number
b: Ground floor area	i: kitchen number
c: 1.st Floor area	j: total wet space area
d: building height	k: number of balconies
e: exterior area	l: number of rooms

f: exterior space space m: hall

Correlation coefficient of the new building cost calculation model (R square) obtained $R^2 = 0,511$

The actual costs of the 7 villas selected randomly from 118 duplex villas are compared and the cost estimates are calculated from the formula obtained above and the average error rate is determined. The model can estimate the cost with an average of 36,68% error (see Table 1.).

Table 1. Cost estimates of 7 different types of villas (test group)

		Type-1	Type-2	Type-3	Type-4	Type-5	Type-6	Type-7	
	Fixed	-238008,88	-238008,88	-238008,88	-238008,88	-238008,88	-238008,88	-238008,88	
Basement Floor Area	A	146,71	146,71	146,71	146,71	146,71	146,71	146,71	
Ground Floor Area	B	1097,48	1097,48	1097,48	1097,48	1097,48	1097,48	1097,48	
First Floor Area	C	496,83	496,83	496,83	496,83	496,83	496,83	496,83	
Building Height	D	22973,81	22973,81	22973,81	22973,81	22973,81	22973,81	22973,81	
Outside Area	E	122,75	122,75	122,75	122,75	122,75	122,75	122,75	
Outside Space Area	F	181,21	181,21	181,21	181,21	181,21	181,21	181,21	
Number of Baths	G	-7466,06	-7466,06	-7466,06	-7466,06	-7466,06	-7466,06	-7466,06	
Number of WCs	H	2995,77	2995,77	2995,77	2995,77	2995,77	2995,77	2995,77	
Number of Kitchen	I	-30215,28	-30215,28	-30215,28	-30215,28	-30215,28	-30215,28	-30215,28	
Total Wet Section Area	J	399,63	399,63	399,63	399,63	399,63	399,63	399,63	
Number of Balconies	K	7157,63	7157,63	7157,63	7157,63	7157,63	7157,63	7157,63	
Number of Rooms	L	3853,73	3853,73	3853,73	3853,73	3853,73	3853,73	3853,73	
Number of Saloon	M	24591,34	24591,34	24591,34	24591,34	24591,34	24591,34	24591,34	
2017 unit prices with construction cost	COST	₺172.515,95	₺291.289,31	₺321.125,12	₺292.478,58	₺189.671,90	₺164.147,83	₺244.376,11	
	NET VALUE	₺105.889,83	₺182.147,00	₺182.147,00	₺250.150,22	₺160.141,27	₺168.057,08	₺203.782,60	
	COST/NET VALUE	1,629	1,599	1,763	1,169	1,184	0,977	1,199	
		0,629	0,599	0,763	0,169	0,184	0,023	0,199	2,567
	ERROR RATE (%)								36,68

The effects of main functional evaluation criteria on the cost of dublex villas were investigated. The most significant data were obtained from 3 ^ 0polinom graphs and the average cost-related equations of these parameters were produced. The graphs of these relations are given below and comments are made.

3.1. Basement Floor Area - Average Cost Relationship

Fig. 1 shows the cost effect of total basement area in a two storey reinforced concrete villa project. While the basement floor area has a positive effect on the cost, it has been observed that it increases the cost in the process after 100 m2 basement area and decreases the cost after 200 m2 area. When the effect of basement floor area on total building cost is examined with this data, the minimum building cost is observed in the sample having 50 m2 basement floor area and the maximum building cost is 210 m2 in the basement floor area.

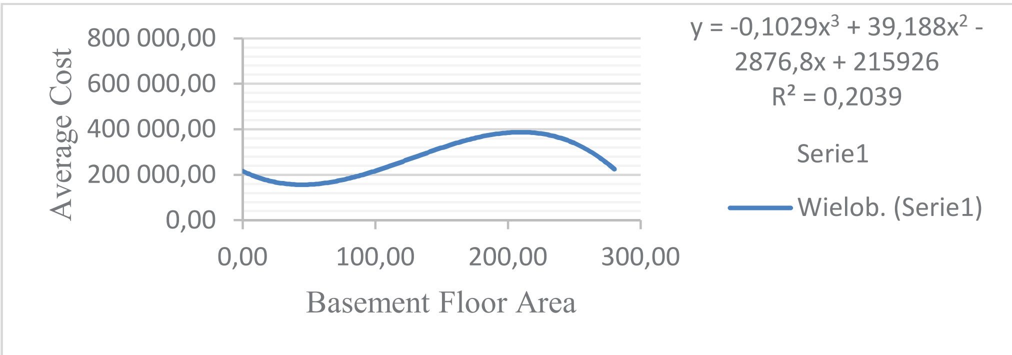

Fig. 1. Basement Floor Area - Average Cost Relationship

3.2. Ground Floor Area - Average Cost Effect

Fig. 2 shows the effect of the total ground floor area in a two storey reinforced concrete villa project on the total building cost. On the basis of this graph which varies in the range of 52-280 m^2, a linearly increasing building cost is seen in relation to the areas with the lowest ground floor area in the sample plane ranging from 52 m^2 to 100 m^2. While the ground floor area changes between the values of 100-200 m^2 do not cause a significant increase in the cost of the building, in the section where the ground floor areas are 200-280 m^2, the graph shows a linear increase in the cost with a slope more than in the first part. The minimum building cost is observed in 52 m^2 and the maximum building cost is 280 m^2. With this data, it is thought that the selection of the ground floor area of the villa, which will be designed for an optimum cost villa design, between 100-200 m^2 can have positive contributions.

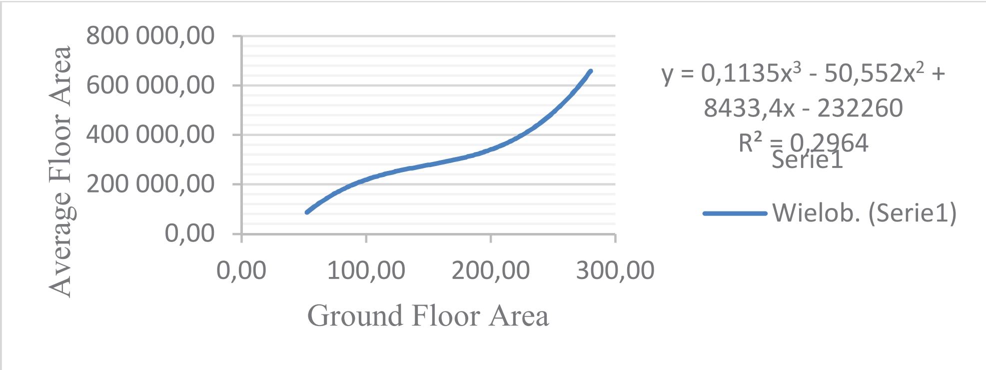

Fig. 2. Ground Floor Area - Average Cost Relationship

3.3. First Floor Area - Average Cost Relationship

Fig. 3. shows the effect of total ground floor area in a two storey reinforced concrete villa project on total building cost. A linearly increased construction cost with a small inclination is seen in the area of the lowest first floor area in the sampling plane, from 50 m^2 to 100 m^2. While the first floor area changes between the values of 100-200 m^2 do not cause a significant increase in the cost of construction, in the section where the first floor areas are 200-280 m^2, the graph shows a linear cost increase with a slope more than the first part. With these data, it is thought that the selection of the 1st floor areas of the type villas up to 200 m^2 can be a positive contribution to the design of an optimum cost villa.

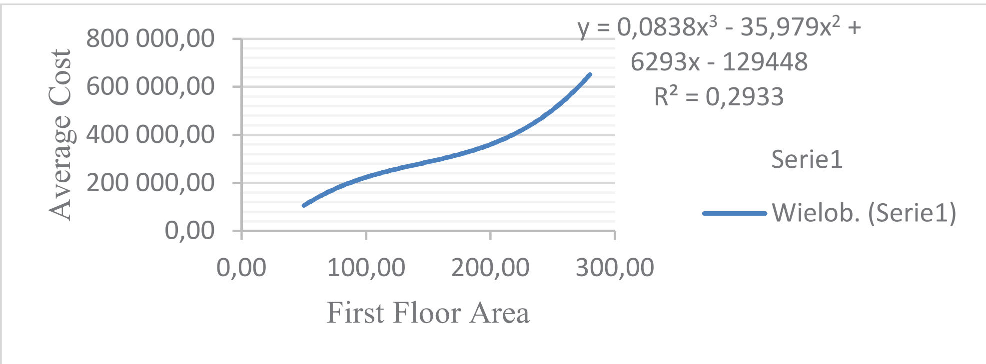

Fig. 3. First Floor Area - Average Cost Relationship

3.4. Building Height - Average Cost Relationship

Fig. 4 shows the effect of the increase in building height on the building cost. Based on this graph, which varies in the range of 5.8-12m, the lowest cost is realized in villas with a height of 5.8 m, while the building cost up to 7 m tall building height shows a linear increase. Building height changes between the values of 7-11m did not show a significant increase in the cost of construction; With these data, it is believed that the selection of the type villas in the 7-11m range may have positive contributions for the design of an optimal cost villa.

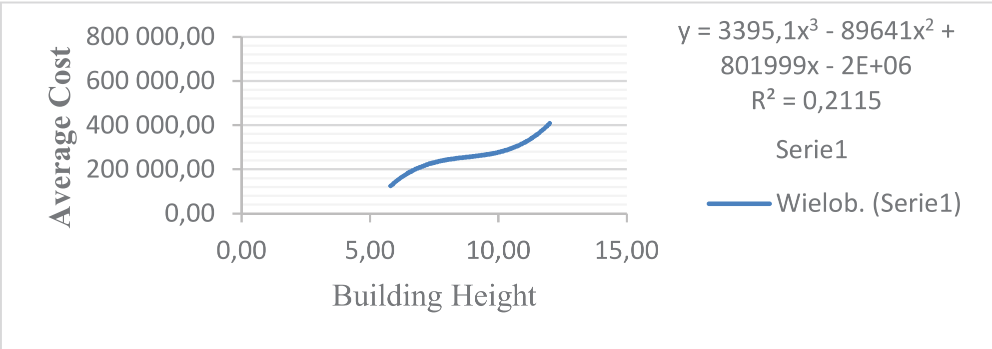

Fig. 4. Building Height - Average Cost Relationship

3.5. Outside Area - Average Cost Relationship

Fig. 5 shows the change in the cost of the building with the increase of the exterior area. When the values taken by the building costs in comparison to the different facade areas varying from 84-982 m^2; While the cost decreases with a decreasing slope between 84-200 m^2 values, between 200-300 m^2 values, there is not much effect on the building cost of the exterior area. While a linear increase is observed in the building cost between 300-750 m^2, the cost of building with an exterior area of more than 750 m^2 decreases with decreasing structure cost. With these data, it is recommended to choose between 200-300 m^2, which corresponds to the lowest building cost, for an cost-effective villa design.

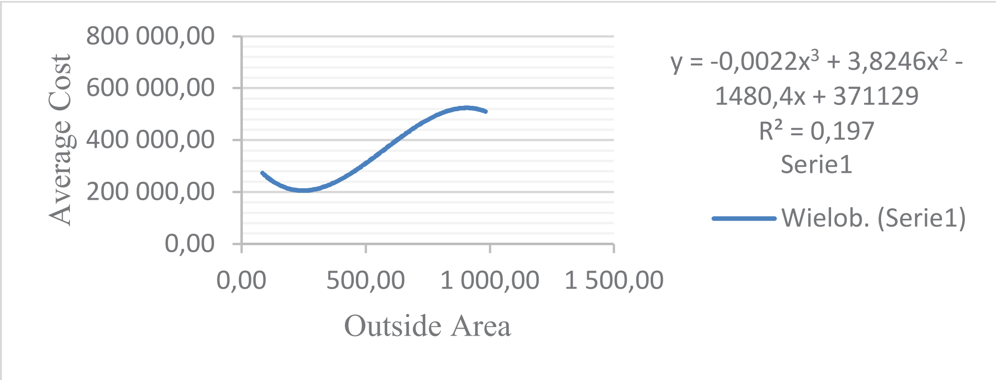

Fig. 5. Outside Area - Average Cost Relationship

3.6. Outside Space Area - Average Cost Relationship

The construction cost of the exterior cavity ratio is shown in Fig. 6. The data in the sample plane corresponds to the 2-148 m^2 exterior cavity area. In the section where the exterior space gap is increased from 10 m^2 to 40 m^2, the cost of building decreases with a decreasing slope. It is observed that the cost of the villas in the exterior space area is reduced. Based on the data obtained, it is recommended to have an external cavity ratio in the range of 40-120 m^2.

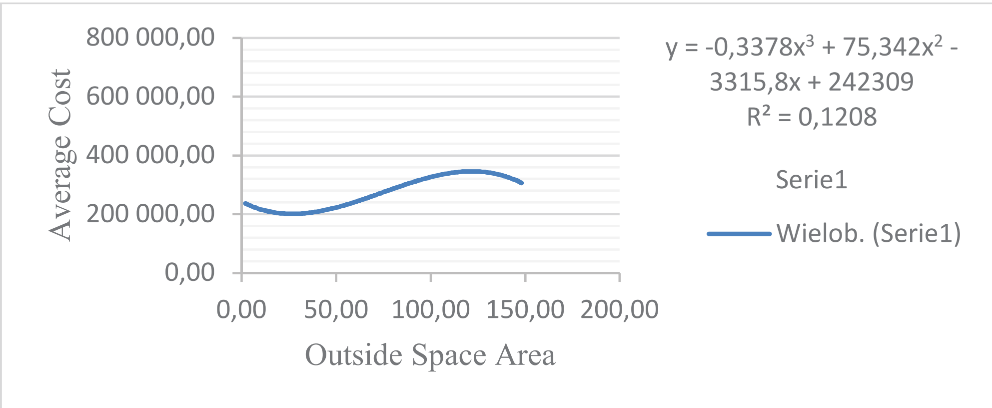

Fig. 6. Outside Space Area - Average Cost Relationship

3.7. Number of Baths - Average Cost Relationship

Fig. 7 shows the effect of the number of bathrooms on the building cost. While the number of bathrooms in the villas with the number of 1 göstermek 2 baths initially decreased, the building cost decreased with a decreasing slope, while the cost of building in the villas with the number of 2-4 baths increased. In villas with more than 4 bathrooms, the cost decreases with increasing inclination. It is observed that the minimum cost villa design has villas with 6 bathrooms and the maximum building cost is 4-5 villas.

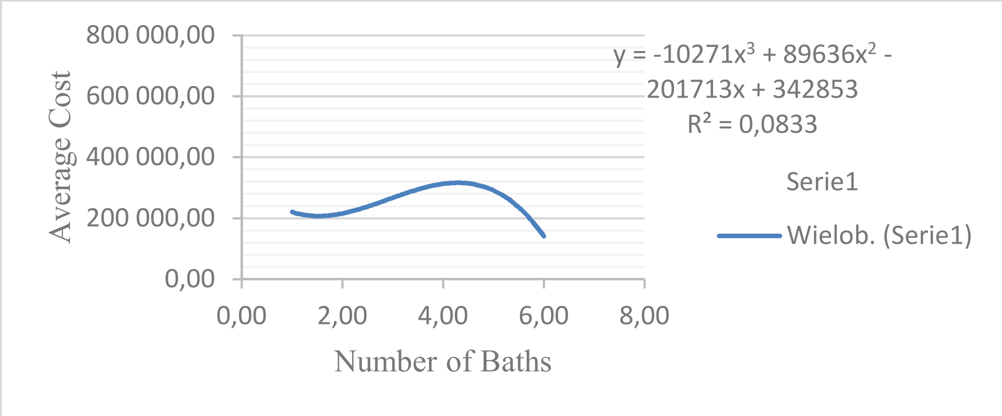

Fig. 7. Number of Baths - Average Cost Relationship

3.8. Number of WCs - Average Cost Relationship

The relation of number of WC to building cost is shown in Fig. 8. While the building cost was increased by 1-2, while the number of wc was more than 2, the building cost increased with an increasing slope at the beginning and the number of wc increased by 3-5 when the building cost increased linearly. . Here, the minimum building cost is provided with 1 wc, wc number increases and building cost will increase.

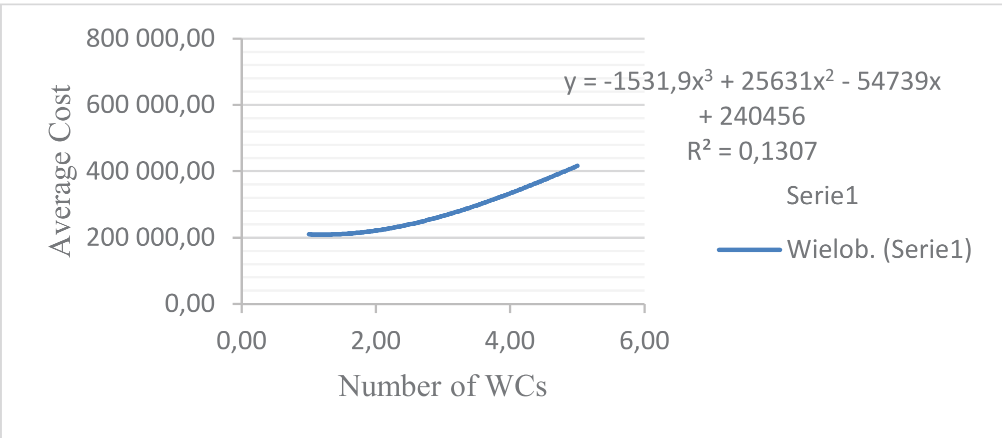

Fig. 8. Number of WCs - Average Cost Relationship

3.9. Number of Kitchen - Average Cost Relationship

Fig. 9 shows the effect of the number of kitchens on the building cost. In these samples, the number of kitchens varies between 1-4 units. Minimum building cost is observed in villas with 1 kitchen, maximum building cost has been observed in villa projects with 4 kitchen. In the villas with 2-4 kitchen number, it is observed that the cost increases linearly.

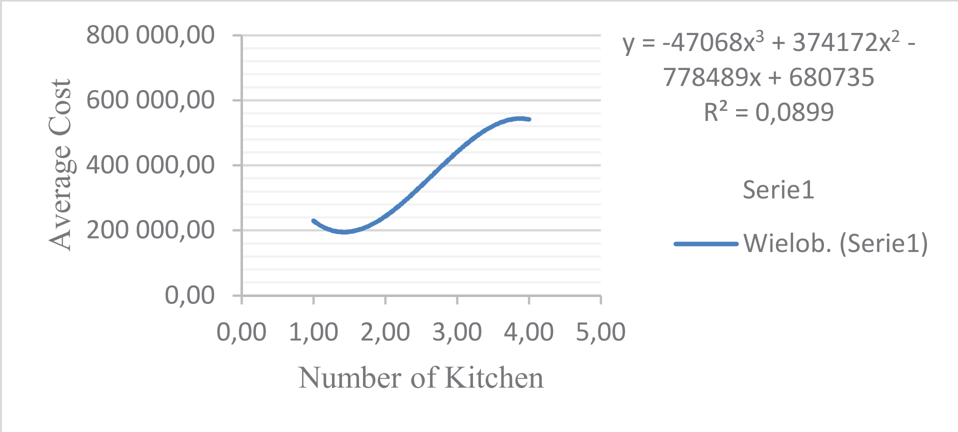

Fig. 9. Number of Kitchen - Average Cost Relationship

3.10. Total Wet Section Area - Average Cost Relationship

Fig. 10 shows the effect of the total wet section area increase on the building cost. According to these data, the lowest cost is realized in villas with a total wet area of 10 m^2 and the building cost up to 20 m^2 total wet section area shows a linear increase. While the total wet section area changes between 20-60 m^2 did not show a significant increase in the construction cost, the building cost in the 60-94 m^2 range showed a linear increase with more slope than the first part. With these data, it is thought that the selection of the total wet part area of the type villas for 20-60 m^2 range may be a positive contribution to the design of an optimum cost villa.

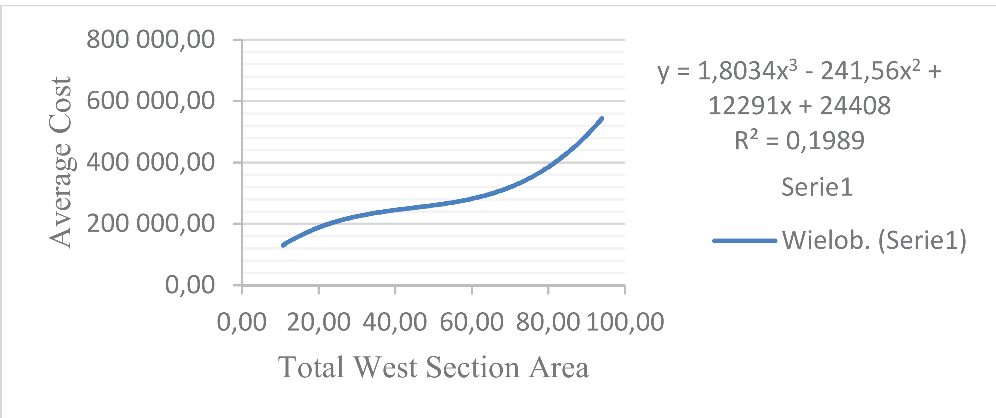

Fig. 10. Total Wet Section Area - Average Cost Relationship

3.11. Number of Balconies - Average Cost Relationship

The relation of the number of balconies to the building cost is shown in Fig. 11. From the graph of the samples, the increase in the number of balconies increased by 1-4 and the building cost increased, while the cost of building increased by 4 when the number of bathrooms was more than 4. The minimum building cost is seen in villas with 1 bathroom and the maximum building cost is seen in villas with 8 bathrooms. As a result, it has been observed that the number of bathrooms has an increasing effect on the building cost.

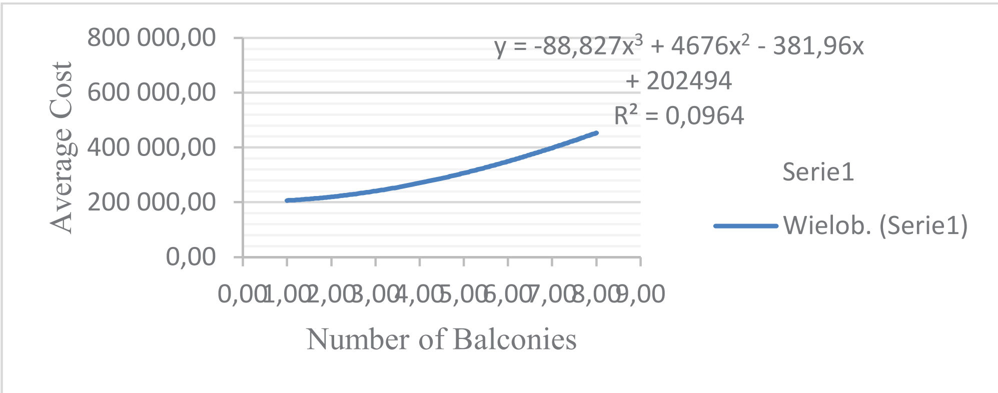

Fig. 11. Number of Balconies - Average Cost Relationship

3.12. Number of Rooms - Average Cost Relationship

Fig. 12 shows the effect of the number of rooms on the building cost. While the number of rooms in the range of 2-6 is increased by a low slope, the cost of building increases with an increasing slope in cases where the number of rooms is more than 6. When the effect of the number of rooms on the building cost was examined, it was observed that the cost of building increased as the number of rooms increased.

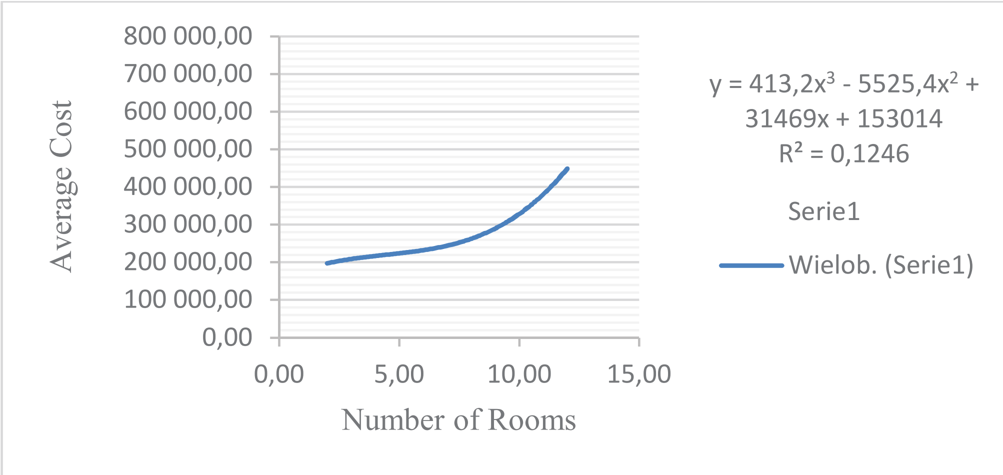

Fig. 12. Number of Rooms - Average Cost Relationship

3.13. Number of Saloon - Average Cost Relationship

The cost of the number of halls is shown in Fig. 13. When the values taken by the building costs in villas varying between 1-6 number of halls; While the cost of building decreases with a decreasing slope in the range of 1-2, the effect of the number of halls on the building cost in the range of 2-4 shows an increasing linear behavior. While there is an increase in the cost of 4-5 saloons, the cost of building in the villas with more than 5 saloons is decreasing. Based on the samples, it was observed that the minimum cost was in villas with 1 hall and the maximum building cost was in villas with 5 halls.

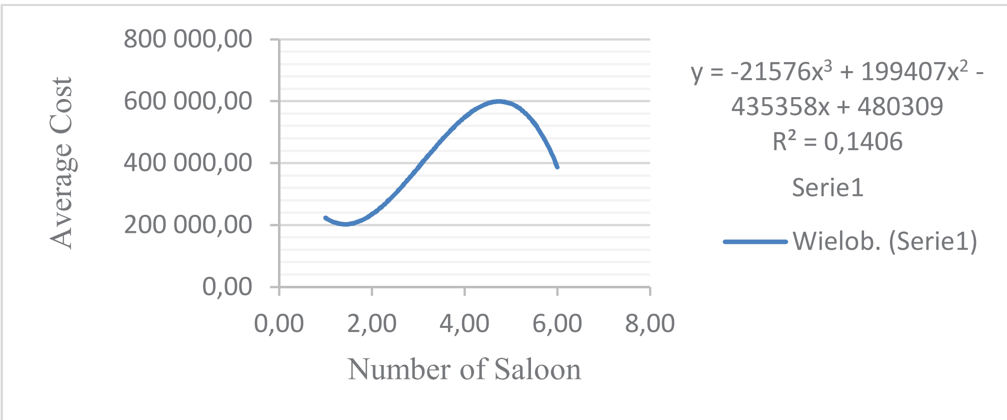

Fig. 13. Number of Saloon - Average Cost Relationship

4. Result

In this study, cost calculations were investigated by using the functional element method in the pre-design stage of the villas with different types of reinforced concrete carrier system. By using the obtained data, the dimensions for optimum cost villa design were determined and the effects of the building characteristics on the building costs were examined. For structures of the aforementioned type; building heights, basement floor areas, 1st floor areas, exterior areas, exterior space spaces, bathroom numbers, number of wc, number of kitchens, total wet areas, number of balconies, number of rooms and changing the number of halls and the changes in building costs were obtained. At the preliminary design stage, the possibility of using this information as a data for design of minimum cost structures has been established. In this way, it is thought that the most suitable design economy can be approached. It is thought that conducting similar studies for different types of buildings will provide benefits to both the investor organizations, end users and the national economy.

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