Comparison of Masonry Construction and Reinforced Concrete Systems with Cost-Benefit Analysis in the Process of Determining the Construction System of an Internship House Project


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ABSTRACT

The Covid-19 Pandemic has necessitated many changes in the education system all over the world. Due to the inexperience in preventing a global epidemic, it is aimed to reduce the spread of the virus by switching to distance education in Turkey as in many countries. Internships that need to be done face to face have been postponed for one year. In the process called new normalization, the sanctions were eased and the hybrid education model, in which the theoretical lessons were made remotely and the practical lessons face to face, was adopted. Within the scope, an internship house project consisting of modules in which one-person rooms and one bathroom-toilet are provided for two rooms has been developed in order for the students of architecture and engineering department to do their internships within the university campus. The aim is to analyse the performance of the masonry construction system with pumice concrete, an earthen material and reinforced concrete system within the framework of the scenario developed above. The efficiency of construction techniques will be compared with the Cost-Benefit Analysis method, which is a numerical analysis method that takes part the themes of the conference as 'Structural behaviour; static, dynamic and numerical analysis methods'. This method consisting of different steps that will be explain comprehensively. Ultimately, it is aimed to determine which of the two construction systems is more suitable.

Keywords: Cost & Benefit Analysis, Masonry Construction System, Pumice Concrete, Reinforced Concrete System, Covid-19 Pandemic.

1 INTRODUCTION

There are many epidemic diseases that have occurred throughout human history. One of these, the Covid-19 epidemic, has caused many changes all over the world since its emergence in 2019. This epidemic, which affects many areas in society as economic, socio-cultural, health, has made it necessary to apply a method called distance education in higher education. Practical lessons could not be done face to face as in the past. It was decided to postpone the internship, which is the subject of this paper and which is a practical education, and the student dormitories were turned into quarantine and a year was gained for the solution of the problem. In the second year of the pandemic, in the process called new normalization, the sanctions were eased and a hybrid education model was introduced, where theoretical lessons are held remotely and practical lessons face-to-face [1].

Within the scope of this model, an internship house project has been developed by us, where the students of architecture and engineering departments can do their summer internships in university campuses and scientists who participate in scientific activities on campus in other seasons can stay. Considering Turkey's economic conditions and the pandemic process, "What should be the construction system of the internship house? Is it more suitable to be built with a reinforced concrete construction system, like many buildings around us, or with another construction system?" An attempt was made to find answers to the questions.

Various calculations have been made assuming that this internship house was first built with a reinforced concrete construction system, and then with a traditional construction method, a masonry construction system (with pumice concrete). According to these calculations, it is tried to decide which construction system will be more suitable.

1.1 Definition of the Problem

Many diseases have been occurred throughout the history of humanity. These unavoidable diseases have turned into a pandemic and affected the whole world from different perspectives. Covid-19 has also affected the world in case of not only socio-cultural, economic but also health and education system. Within the framework of the hybrid educational system, the need for a sterile place where internships can be held has arisen.

1.2 Purpose of the Study

The internship house project is designed using masonry and reinforced concrete construction systems. Pumice concrete, a natural building material, is used for masonry system. Also, brick is used as filling material for the reinforced concrete system. The aim of the paper is to analyse the performance of the construction systems within the framework of the scenario developed above. As a result, it is aimed to determine which of the two construction systems and construction materials is more suitable for this scenario.

1.3 Context of the Study

Performance analysis and comparison of all construction systems can be done with the Cost-Benefit Analysis method. Within the scope of the paper, the reinforced concrete system, which is the most widely applied construction system in Turkey, and the masonry construction system in which pumice concrete material is used are compared in terms of many criteria.

1.4 Methodology of the Study

The method used in this study is the Cost-Benefit Analysis method, which has been used in various studies for a long time. In Tapan's book "Mimarlıkta Değerlendirme Aracı Olarak Fayda-Değer Analizi " published in 1980, the Cost-Benefit Analysis method is explained as a method that is used when choosing among many alternatives and aims to determine the value provided by these alternatives. The benefit value is formed by evaluating the benefits provided by the system parts of an alternative one by one. It is a method that depends on a value system related to the goal system and the preferences of the decision maker, not as a tangible size of goal-related utility [2].

In this context, each construction system is analysed in terms of its positive or negative features. The data with different units obtained at the end of the analysis are converted into a single value system. This method consists of determining the necessary criteria for comparing the construction systems with each other, ranking these criteria according to their importance, calculating the success points of the construction systems against each criterion and the result value obtained by the construction system 'Fig. 1'.

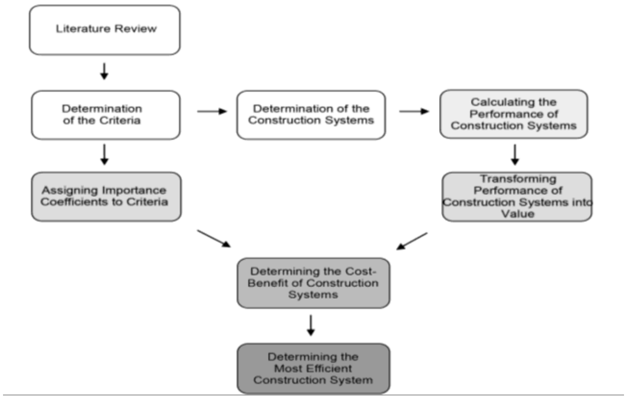

Figure 1. Methodology of the Study

2 FINDINGS

The architectural project was created in modules where each student stays in single rooms and a bathroom-toilet is used in two rooms. Each module is 3 meters x 7 meters in size and designed to have a net usage area of 21 sqm. During the summer months, the architecture students will stay for 6 weeks and the engineering students for the other 6 weeks; during the academic year, an accommodation unit that can host up to 100 people is designed to be used by the academic staff attending the scientific meetings on the campus. 25 of these units, which have ground floor and first floor, are located in an area close to the cafeteria within the campus 'Figs. 2 and 3'.

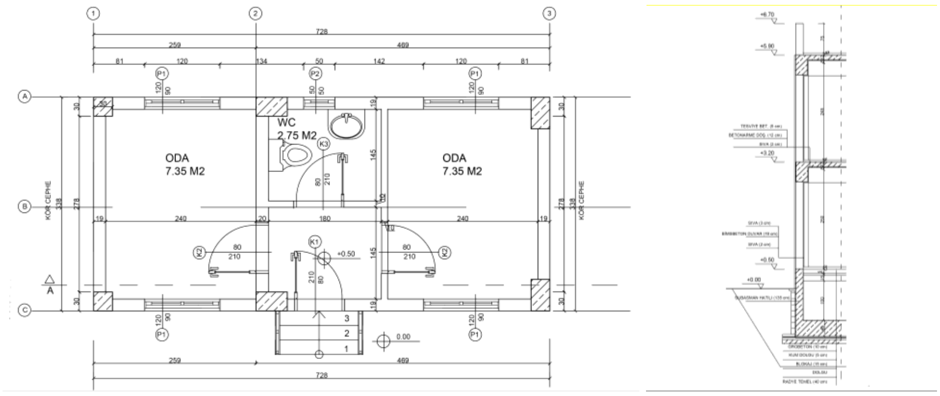

Figure 2. The Internship House Project Reinforced Concrete System Plan and Section

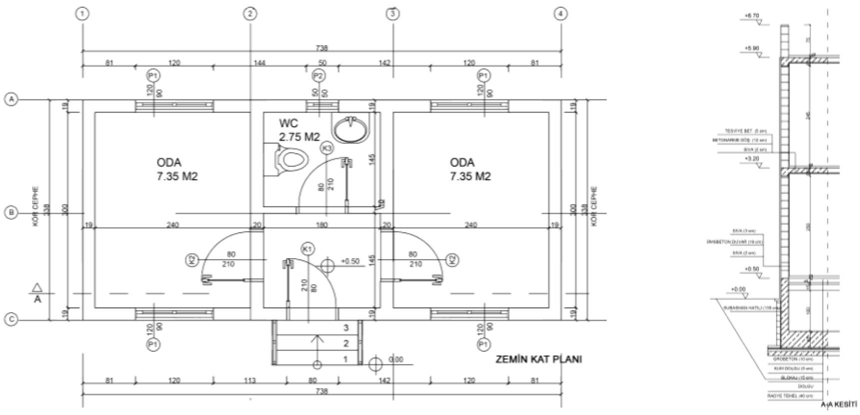

Figure 3. The Internship House Project Masonry System Plan and Section

2.1 Criteria

It is foreseen that the construction of the internship house, which will be built within the framework of the architectural project, will start at the end of February, the beginning of the 2020-2021 spring term, and will be completed by the start of the internship period in July (approximately 4 months). In addition, since the cost of construction is covered by the Rectorate, choosing a low-cost construction system should be among the priorities.

Two different projects of the internship house project, both masonry and reinforced concrete construction systems, were drawn by keeping the net usage area constant at 21 sqm, and the calculations were made according to these projects. The buildings designed with these two construction systems were compared within the framework of 8 criteria seen in Table 1 in the context of Cost-Benefit Analysis. Since a raft foundation was used for both structures, calculations were made considering the structure above the sub-basement level in the context of comparison. At the same time, cost calculations were made taking into account the rough construction.

Table 1. Main Criteria Determined within the framework of Cost-Benefit Analysis

C_1- Cost of the Project	C_5- Ease of Production of the Material in Turkey
C_2- Construction Time	C_6- Ease of Transportation
C_3- Need for Skilled Workers During the Project	C_7- Ease of Instalment
C_4- Equipment and Vehicle Need During the Project	C_8- Sustainability of the Construction System

2.2 Importance Coefficients

After the criteria were determined, their importance levels were determined by considering the pandemic conditions. In this process, a discussion with 16 participants, including the senior undergraduate students of the Department of Architecture, was held and the arithmetic average of the results was taken and the importance coefficients were assigned [Table. 2]. Within the framework of the prepared scenario, the most important of the 8 criteria was given a maximum of 4 and the least important one was given a minimum of 1 and the other six criteria were given points between these numbers and the importance coefficients were determined.

Table 2. Importance Coefficients of Each Criterion

Importance Coefficients (1<I.C. <4)	Main Criteria (The most important 4 point, the least 1 point)
$I.C._1=3.75$	C_1- Cost of the Project
$I.C._2=3.70$	C_2- Construction Time
$I.C._3=2.10$	C_3- Need for Skilled Workers During the Project
$I.C._4=2.10$	C_4- Equipment and Vehicle Need During the Project
$I.C._5=2.40$	C_5- Ease of Production of the Material in Turkey
$I.C._6=2.00$	C_6- Ease of Transportation
$I.C._7=1.40$	C_7- Ease of Instalment
$I.C._8=3.30$	C_8- Sustainability of the Construction System

2.3 Performance Calculations and Scoring

In the third stage, scores were made on the basis of criteria, taking into account both systems. There are two types of criteria, main and sub. Sub-criteria were created by detailing the main criteria. The value of each main criterion is found by the formula in Table 3. This formula contains the importance coefficients and values of the sub-criteria of the main criterion and is used within the scope of Cost-Benefit Analysis [Table 3].

Table 3. The Formula Used Within the Framework of Cost-Benefit Analysis [3].

$B_j = \frac{\sum_{i=1}^{m}\left(V_{(i,j)} \times IC_i\right)}{\sum_{i=1}^{m} IC_i}$ [j=1,2,…,n; (i=1, 2,…,m)]	
B: Benefit of Main Criterion	I.C.: Importance Coefficient of Sub Criterion
In this study m=8 (Criteria), n=2 (construction system) was taken.	V: Value of Sub Criterion

2.3.1 Cost of the Project

For the rough construction cost criterion, all the construction stages of the superstructure are written. The total cost was reached by taking the quantities and using the pose numbers for 2021 and the unit price list published by the Ministry of Environment and Urbanization. [4]. The masonry construction system made using pumice concrete is 22% cheaper than the reinforced concrete construction system in terms of cost. [Table 4].

Table 4. Comparison of the Costs of the Systems

C_2- Cost of the Project	Reinforced Concrete System Total Cost	Masonry Construction Total Cost
	48,964.46 ₺	38,343.31₺

2.3.2 Construction Time

For the construction time, the Gantt Diagram was created by us using the working times in the same pose numbers. Rough structure construction times were found for both building systems. Coatings with fine construction materials are excluded from the cost. In this study, a total of 6 craftsman crew, including one carpenter, cold blacksmith, concrete worker, mason and two plasterers, were used. As a result of the Gantt Diagrams, the construction period with the masonry construction system took 40 days and the reinforced concrete system took 43 days. The masonry system with pumice concrete can be built in 7% less time than the reinforced concrete 'Fig. 4'.

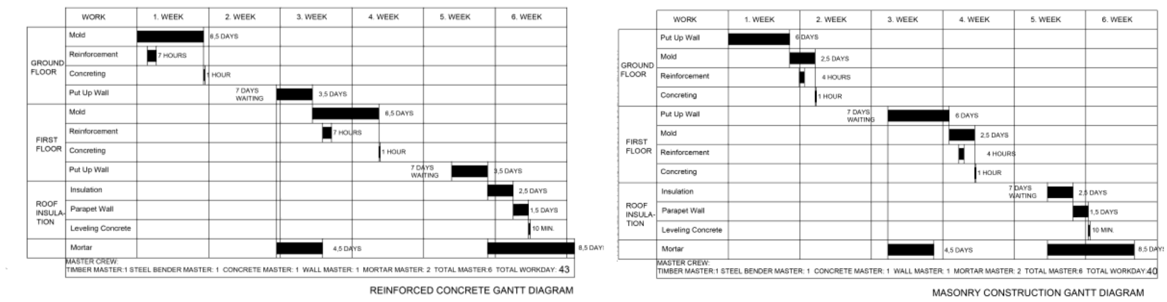

Figure 4. Gantt Diagrams of Reinforced Concrete and Masonry Construction Systems

2.3.3 Need for Skilled Workers During the Project

Three sub-criteria were created to determine the value of this criterion. These criteria are 'No need for specially trained workers', 'Availability of skilled workers across the country', 'Unskilled workers ability to learn the work done skilled ones'. The importance coefficients of three sub-criteria were created with the study group of 16 people. Comparative values were determined for both systems. In the context of the definition of the criterion, 1 was given to the one with the lower performance from the two construction systems and a comparative value was determined for the other [Table 5]. Values are also determined based on performance for each criterion. Values in Table 5 are substituted in the formula in Table 3 and the value for the main criterion is calculated.

Table 5. Third Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_3- Need for Skilled Workers During the Project	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(3.1)}$- No need for specially trained workers	$I.C._{(3.1)}= 1.8$	$V_{(3.1)}= 1.0$	$V_{(3.1)}= 1.6$
$C_{(3.2)}$- Availability of skilled workers across the country	$I.C._{(3.2)}= 1.1$	$V_{(3.2)}= 1.35$	$V_{(3.2)}= 1.0$
$C_{(3.3)}$- Unskilled workers ability to learn the work done skilled ones	$I.C._{(3.3)}= 1.4$	$V_{(3.3)}= 1.0$	$V_{(3.3)}= 1.6$
Value of the Construction Systems		$V_{(3.r)}= 1.08$	$V_{(3.m)}= 1.44$

2.3.4 Equipment and Vehicle Need During the Project

Five sub-criteria were created to determine the value of this criterion. These criteria are 'Obligation to use mold', 'Obligation to use working scaffold', 'Obligation to use special construction machinery', 'Intensity of using truck mixer and concrete pump', 'Obligation to use lifter'. Values are also determined comparatively [Table 6].

Table 6. Forth Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_4- Equipment and Vehicle Need During the Project	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(4.1)}$- Obligation to use mold	$I.C._{(4.1)}$= 1.5	$V_{(4.1)}$= 1.0	$V_{(4.1)}$= 2.5
$C_{(4.2)}$- Obligation to use working scaffold	$I.C._{(4.2)}$= 1.3	$V_{(4.2)}$= 1.0	$V_{(4.2)}$= 2.0
$C_{(4.3)}$- Obligation to use special construction machinery	$I.C._{(4.3)}$= 1.7	$V_{(4.3)}$= 1.1	$V_{(4.3)}$= 1.0
$C_{(4.4)}$- Intensity of using truck mixer and concrete pump	$I.C._{(4.4)}$= 1.6	$V_{(4.4)}$= 1.0	$V_{(4.4)}$= 2.5
$C_{(4.5)}$- Obligation to use lifter	$I.C._{(4.5)}$= 1.7	$V_{(4.5)}$= 1.0	$V_{(4.5)}$= 1.0
Value of the Construction Systems		$V_{(4.r)}$= 1.02	$V_{(4.m)}$= 1.76

2.3.5 Ease of Production of the Material in Turkey

Two sub-criteria were created to determine the value of this criterion. These criteria are 'Production prevalence of building components throughout Turkey' and 'High annual production capacity of building components' [Table 7].

Table 7. Fifth Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_5- Ease of Production of the Material in Turkey	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(5.1)}$- Production prevalence of building components throughout Turkey	$I.C._{(5.1)}$= 1.4	$V_{(5.1)}$= 2.6	$V_{(5.1)}$= 1.0
$C_{(5.2)}$- High annual production capacity of building components	$I.C._{(5.2)}$= 1.4	$V_{(5.2)}$= 2.1	$V_{(5.2)}$= 1.0
Value of the Construction Systems		$V_{(5.r)}$= 2.35	$V_{(5.m)}$= 1.0

2.3.6 Ease of Transportation

Five sub-criteria were created to determine the value of this criterion. These criteria are 'Ease of transportation from the production site to the construction site', 'Simple to replace building materials and components', 'Difficulty in transporting building components within the construction site due to weight and quantity', 'The possibility of breakage of the building components during transportation to the construction site or when they are unloaded to the construction site' and 'Road transport difficulty due to the dimensions of the components to be transported' [Table 8].

Table 8. Sixth Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_6- Ease of Transportation	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(6.1)}$- Ease of transportation from the production site to the construction site	$I.C._{(6.1)}$= 1.6	$V_{(6.1)}$= 1.0	$V_{(6.1)}$= 1.1
$C_{(6.2)}$- Simple to replace building materials and components	$I.C._{(6.2)}$= 1.5	$V_{(6.2)}$= 1.0	$V_{(6.2)}$= 2.5
$C_{(6.3)}$- Difficulty in transporting building components within the construction site due to weight and quantity	$I.C._{(6.3)}$= 1.5	$V_{(6.3)}$= 1.0	$V_{(6.3)}$= 1.0
$C_{(6.4)}$- The possibility of breakage of	$I.C._{(6.4)}$= 1.9	$V_{(6.4)}$= 1.75	$V_{(6.4)}$= 1.0

the building components during transportation to the construction site or when they are unloaded to the construction site			
$C_{(6.5)}$- Road transport difficulty due to the dimensions of the components to be transported	$I.C._{(6.5)}= 1.3$	$V_{(6.5)}= 1.0$	$V_{(6.5)}= 1.1$
Value of the Construction Systems		$V_{(6.r)}= 1.18$	$V_{(6.m)}= 1.32$

2.3.7 Ease of Instalment

Two sub-criteria were created to determine the value of this criterion. These criteria are 'Easy laying of plumbing under construction' and 'Easy to make plumbing repairs during use' [Table 9].

Table 9. Seventh Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_7- Ease of Instalment	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(7.1)}$- Easy laying of plumbing under construction	$I.C._{(7.1)}= 1.3$	$V_{(7.1)}= 1.75$	$V_{(7.1)}= 1.0$
$C_{(7.2)}$- Easy to make plumbing repairs during use	$I.C._{(7.2)}= 1.3$	$V_{(7.2)}= 1.75$	$V_{(7.2)}= 1.0$
Value of the Construction Systems		$V_{(6.r)}= 1.75$	$V_{(6.m)}= 1.0$

2.3.8 Sustainability of the Construction System

Six sub-criteria were created to determine the value of this criterion. These criteria are 'Whether it is harmless to the environment', 'Whether thermal insulation is needed (on the wall/ceiling)', 'Insufficient amount of residual product at the end of production', 'Low cost of demolition', 'Whether the material is reusable after demolition' and 'Whether the demolition process harms the environment' [Table 10].

Table 10. Eighth Criterion's Value for Reinforced Concrete and Masonry Construction Systems

C_8- Sustainability of the Construction System	Importance Coefficients of Sub criteria	Values of Sub criteria (Reinforced Conc.)	Values of Sub criteria (Masonry Const.)
$C_{(8.1)}$- Whether it is harmless to the environment	$I.C._{(8.1)}= 2.8$	$V_{(8.1)}= 1.0$	$V_{(8.1)}= 2.75$
$C_{(8.2)}$- Whether thermal insulation is needed (on the wall/ceiling)	$I.C._{(8.2)}= 1.9$	$V_{(8.2)}= 1.0$	$V_{(8.2)}= 2.0$
$C_{(8.3)}$- Insufficient amount of residual product at the end of production	$I.C._{(8.3)}= 1.6$	$V_{(8.3)}= 1.1$	$V_{(8.3)}= 1.5$
$C_{(8.4)}$- Low cost of demolition	$I.C._{(8.4)}= 1.1$	$V_{(8.4)}= 1.0$	$V_{(8.4)}= 2.25$
$C_{(8.5)}$- Whether the material is reusable after demolition	$I.C._{(8.5)}= 2.1$	$V_{(8.5)}= 1.0$	$V_{(8.5)}= 1.0$
$C_{(8.6)}$- Whether the demolition process harms the environment	$I.C._{(8.6)}= 1.8$	$V_{(8.6)}= 1.0$	$V_{(8.6)}= 2.25$
Value of the Construction Systems		$V_{(6.r)}= 1.01$	$V_{(6.m)}= 1.99$

2.4 Discussion

For the first criterion, the project cost, the values of the reinforced concrete and masonry construction systems were found with the help of quantity and unit price calculations. It has been concluded that the one built with reinforced concrete system is 22% more costly than masonry. For the second criterion, the construction time, Gantt diagrams were created according to the quantity. It has been concluded that the construction speed of the reinforced concrete system is 7% slower than the masonry. For the third criterion in which the need for skilled workers is compared, the masonry system is more advantageous. The masonry system is more advantageous than reinforced concrete for the fourth criterion, equipment and vehicle needs. Contrary to the first 4 criteria, it is seen that reinforced concrete is more advantageous in the comparison of the criteria of ease of production of materials. For the sixth criterion comparing the ease of transportation, the masonry system is more advantageous. It is seen that the reinforced concrete system is more advantageous for the ease of laying the installation system. For the last criterion, sustainability, it is seen that the masonry system is advantageous with a significant difference [Table 11].

Table 11. Benefits of the Construction Systems

Main Criteria	Importance Coefficient	Values of Reinforced Concrete System	Values of Masonry Const. System
C_1- Cost of the Project	I.C.$_1$= 3.75	$V_{(1.r)}$= 1.0	$V_{(1.m)}$= 1.22
C_2- Construction Time	I.C.$_2$= 3.70	$V_{(2.r)}$= 1.0	$V_{(2.m)}$= 1.07
C_3- Need for Skilled Workers During the Project	I.C.$_3$= 2.10	$V_{(3.r)}$= 1.08	$V_{(3.m)}$= 1.44
C_4- Equipment and Vehicle Need During the Project	I.C.$_4$= 2.10	$V_{(4.r)}$= 1.02	$V_{(4.m)}$= 1.76
C_5- Ease of Production of the Material in Turkey	I.C.$_5$= 2.40	$V_{(5.r)}$= 2.35	$V_{(5.m)}$= 1.0
C_6- Ease of Transportation	I.C.$_6$= 2	$V_{(6.r)}$= 1.18	$V_{(6.m)}$= 1.32
C_7- Ease of Instalment	I.C.$_7$= 1.40	$V_{(7.r)}$= 1.74	$V_{(7.m)}$= 1.0
C_8- Sustainability of the Construction System	I.C.$_8$= 3.3	$V_{(8.r)}$= 1.01	$V_{(8.m)}$= 1.99
Benefits of the Construction Systems		**B_r= 1.23**	**B_m= 1.36**

3 RESULTS

Within the scope of the architectural project developed the prepared scenario, two construction systems were compared within the framework of 8 criteria. According to the analysis results obtained in Table 11, it is seen that the masonry system is more effective and suitable than the reinforced concrete system for 6 criteria, including cost, construction time and sustainability criteria, which have high importance coefficients, and the opposite is true for only 2 criteria with low importance coefficient. When the total success points of both systems are compared, the score of the reinforced concrete structure is 1.23, the score of the masonry construction was calculated as 1.36. Within the framework of this scenario, it is concluded that it would be more appropriate to build a masonry structure. However, the fact that a maximum of two floors can be built with the masonry system in Turkey is the most important factor in not preferring masonry structures.

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