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Comparison of Cold-Formed Steel and Reinforced Concrete Construction Systems Efficiency in Context of the Pandemic Hospital

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Abstract

The study aims to compare cold-formed steel (CFS), which is the construction system for emergency hospitals are quickly completed and used in an epidemic in Türkiye and the reinforced concrete (RC) construction system, which is the most preferred in Türkiye. This comparison includes criteria such as time, cost, sustainability, sound and thermal isolation, mechanic ventilation, instalment, transportation and production of building elements, natural lighting, disassembly-reassembly, and spatial flexibility. Projects were created based on the plan of Prof. Dr. Feriha Öz Emergency Hospital, built in Türkiye during the COVID-19 period. This comparison is made with the scientific Cost-Benefit Analysis method. Epidemics are the subject of many studies. However, researching the construction system will be more effective in the context of Türkiye, which is a unique and nationally valuable topic. It is essential to examine. The findings show CFS is more effective than RC in Türkiye during an epidemic. This situation parallels the preferred construction system for hospital applications in Türkiye.

Keywords: *Cold-formed steel construction system, reinforced concrete construction system, Covid-19 pandemic outbreak, pandemic hospitals, cost & benefit analysis.*

Hafif Çelik ve Betonarme Karkas Yapım Sistemlerinin Etkinliğinin Pandemi Hastanesi Bağlamında Karşılaştırılması

Öz

Araştırmanın amacı salgın durumunda Türkiye'de hızla tamamlanıp hizmete sunulan acil durum hastanelerinin yapım sistemi olan hafif çelik ile Türkiye'deki yapılarda en çok tercih edilen betonarme karkas yapım sisteminin karşılaştırılmasıdır. Karşılaştırma hız, maliyet, sürdürülebilirlik, ses ve ısı yalıtımı, mekanik havalandırma, tesisat, yapı malzemelerinin taşınması ve üretilmesi, doğal aydınlatma, sökülüp kurulabilirlik ve mekânsal esneklik kriterleri bağlamında yapılmıştır. Araştırmanın kapsamını, Covid-19 döneminde Türkiye'de inşa edilmiş olan hastanelerde tercih edilen hafif çelik yapım sistemi ve betonarme yapım sistemi oluşturmaktadır. Bu çerçevede Covid-19 döneminde Türkiye'de inşa edilmiş olan Prof. Dr. Feriha Öz Acil Durum Hastanesi'nin planı örnek alınarak projeler oluşturulmuştur. Bu yapım sistemleri bilimsel bir yöntem olan Fayda-Değer Analizi ile karşılaştırılmıştır. İnsanlık için tehdit oluşturan salgınlar birçok araştırmaya konu olmuştur. Fakat Türkiye bağlamında daha etkin olacak yapım sisteminin araştırılması özgün ve milli değer taşıyan bir konudur. Bu anlamda araştırılması önemlidir. Araştırma sonucunda salgın durumunda inşa edilecek hastane fonksiyonlu bir yapı için Türkiye şartlarında hafif çelik yapım sisteminin betonarmeye göre daha etkin olduğu saptanmıştır. Bu durum Türkiye'de uygulanan salgın hastaneleri için tercih edilmiş yapım sistemi ile paralellik göstermektedir.

Anahtar kelimeler: *Hafif çelik yapım sistemi, betonarme karkas yapım sistemi, Covid-19 pandemisi, acil durum hastanesi, fayda-değer analizi.*

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1. Introduction

Throughout human history, many epidemic situations occurred. In recent history, unprecedented pandemic outbreaks such as severe acute respiratory syndrome (SARS) coronavirus (SARS-CoV), Middle East respiratory syndrome (MERS) coronavirus (MERS-CoV) was occurred. COVID-19 is the latest example of a devastating pandemic disease (Morens et al., 2020a; Morens et al., 2020b).

As the pandemic outbreaks have effects worldwide, they also have significant effects across each country. Every country needs to use its resources most effectively and get through the pandemic periods healthily. One of the most critical steps in architecture and construction is to design and build pandemic hospitals. It is necessary to treat only positive cases during the pandemic. But existing hospitals cannot provide adequate health services to patients who are negative for Covid-19. Uninfected individuals also need to go to the hospital due to different ailments have a significant risk of being infected with this disease. Even if the existing hospitals convert into pandemic hospitals, they do not have sufficient capacity for positive cases. This situation not only disrupts societal welfare but also can severely damage the health infrastructure of the country. Since this research is carried out for the conditions of Türkiye and aims to determine a more effective construction system, it seeks to reach the result by using our country's resources and potential most efficiently.

Epidemics have had a significant impact on all humanity in many ways. Also, Covid-19 has affected society in many areas, such as socio-cultural, health and economic. This situation involving social life has substantial effects on the fields of architecture and engineering. While the epidemic was in effect, there was a need for places to treat the infected individuals in isolation from society. To solve this problem, pandemic hospitals, produced with different construction systems, have been established in many countries. Some of these include; Rafah Field Hospital, built by masonry construction in Gaza; Field Hospital, built by steel construction in Russia; triage and treatment units built by pneumatic system in Italy; Huoshenshan and Leishenshan Hospitals, built by container-type prefabricated units in China. In Türkiye, Prof. Dr. Murat Dilmener Emergency Hospital and Prof. Dr. Feriha Öz Emergency Hospital were designed and constructed by cold-formed steel construction. It was completed in forty-five days and has 1008 bed capacity (Öztürk & Savaşır, 2020). COVID-19 disease emerged in China at the end of 2019, but the declaration of a pandemic by the WHO (World Health Organization) and the first official case detection in Türkiye took place on March 11 (Republic of Türkiye Ministry of Health, 2020).

Within the scope of this study, cold-formed steel (CFS) construction and reinforced concrete (RC) construction systems, the preferred construction system for pandemic hospitals built in Türkiye during the pandemic period, are compared. The RC construction constitutes most of the building stock in Türkiye. However, during the pandemic, CFS construction was preferred over the RC construction system. This article investigates the reasons for this situation and compares these two construction systems using the Cost-Benefit Analysis (CBA) method. Istanbul was the preferred application area of emergency hospitals during the Covid-19 pandemic. In the study, Izmir is the application area.

This research aims to compare CFS construction, the construction system of Türkiye's emergency hospitals to be quickly completed and used during the pandemic, and Türkiye's most preferred RC construction. More than %90 of the structures built during and after the pandemic is RC construction (Turkish Statical Institute (TUIK, 2020). CBA method scientific method determined which of the two construction systems is more effective/appropriate in the conditions of Türkiye.

Compared to other hospitals, different design criteria and construction methods are used for pandemic hospitals. In this respect, it is crucial to examine the world and Turkish literature on this subject and to investigate the solutions developed by the world's countries to overcome this situation. As Türkiye, it is vital to seek a solution to this problem with its resources and innovative methods.

Due to the increase in positive cases since the beginning of the Covid-19 period, hospital capacities have been questioned. The emphasis is on the changed needs and that new arrangements should be possible in existing hospitals to treat Covid-19 patients (McCabe et al., 2020). One of the first hospitals built during the pandemic was Leishenshan Hospital in Wuhan, China. The Xiaotangshan Hospital, built in Beijing during the 2003 SARS pandemic, was taken as a model in the design and construction of this hospital. Xiaotangshan Hospital was effective in the 2003 pandemic and has been influential in determining a safe hospital strategy for China for future pandemics. The construction of Leishenshan Hospital, which was in this context, is also a model for many pandemic hospitals built in different countries. The structure of this hospital was with a prefabricated modular system and had a capacity of 1600 patients. In addition, one of its most important features is that the construction took only 12 days. The shortness of the construction time depends on the technological methods used. Leishenshan Hospital is one of the two hospitals whose design and construction were completed quickly with BIM technology. The hospital is said to have worked very actively in the treatment and reduced mortality rates in this process (Luo et al., 2020).

These studies contain information about the hospitals used during the pandemic period. This information is for use this research. However, the research aims to examine the construction systems of the hospitals with the CBA method and to determine a more effective construction system in Türkiye's conditions.

Some studies emphasize the significance of the CBA method. It is argued that products made with the prefabrication method will be more efficient. In this context, the prefabricated construction system should be encouraged by investigating the cost and benefit of prefabricated structures in real building projects (Hong et al., 2018). Studies show that people working on construction projects waste a lot of time to collect data. Hence, manual execution of data collection reduces efficiency and offers less effective project management. The CBA method applications in this context achieved the most effective results and saved time (Vaughan et al., 2013).

The CBA method was used in the above mentioned studies. There is no research conducted on calculating the construction systems of epidemic hospitals with the CBA method and the most effective construction system. Although there are many articles written in the field of health in the literature, there are only a few publications worldwide on the examination of the construction systems of hospitals built during the pandemic periods. For this reason, the research subject is significant and valuable.

2. Material and Method

This research uses the CBA method, which was used in various scientific studies for a long time. The CBA method is a method that is used in the case of 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. The method depends on a value system related to the goal system and the decision maker's preferences, not as a tangible size of goal-related utility (Tapan, 1980).

This research analyses two construction systems regarding their positive or negative features. The data obtained at the end of the study, which have different units, are converted into a single value system. Then, the success points obtained by the construction system according to its distinct characteristics are collected by considering their importance level. These points amount to the benefit each building system has. The use of this method for the research can be explained in detail as follows.

The scope of the CBA, the research first started with a literature review. The architectural space designs and construction systems of the pandemic hospitals built in Türkiye were examined. After these examinations, the construction system applied in pandemic hospitals was determined. For comparison, the most preferred construction system was also determined. In this context, two construction systems were determined to be compared CFS construction and RC construction systems.

In the second stage, the criteria such as construction period and construction cost etc., which are effective in the design and construction of pandemic hospitals, are determined. These criteria play a decisive role in comparing the preferred construction systems in hospitals. A survey study including the criteria was carried out, and the importance coefficients of these criteria were determined with the help of the survey. The questionnaire was applied to architects, civil engineers and contractors involved in designing and constructing the pandemic hospitals. The questionnaire asked how to determine the importance level (between 1 and 5) of the predetermined criteria (construction speed, cost, etc.). Importance coefficients were assigned to the criteria according to the survey data obtained. While tangible results were obtained with mathematical calculations for some criteria, sub-criteria were created. Even though the importance coefficients of the main criteria were determined with the help of questionnaires, the importance coefficients of the sub-criteria were evaluated by the authors of this article and in light of some foreseen technical results.

After completing the survey with the relevant people, the data obtained were compiled for use in the following steps. After this process, the performance calculations of each construction system were based on each evaluation criterion. Since these performance calculations obtained have different units (cost is obtained in "TL", construction period is obtained in "hours or days", etc.), they must be converted to a standard unit of value. The performance values of each construction system are obtained by converting to a standard unit.

As a final step, the importance coefficients obtained with the survey data and the performance values of the construction system were multiplied. After this step, which was repeated for both construction systems evaluated in the research, the cost-benefit of each construction system was determined. The CBA of both construction systems were compared, and the construction system with the higher success score was determined as the more effective one. In this way, the most effective result aimed at the research is achieved. With this feature, the research subject is essential and has an original quality. It is of great importance in bringing criticism to the emergency (pandemic) hospitals built in Türkiye and being a pioneer in terms of benefit value for the emergency hospitals planned to be built from now on (Figure 1).

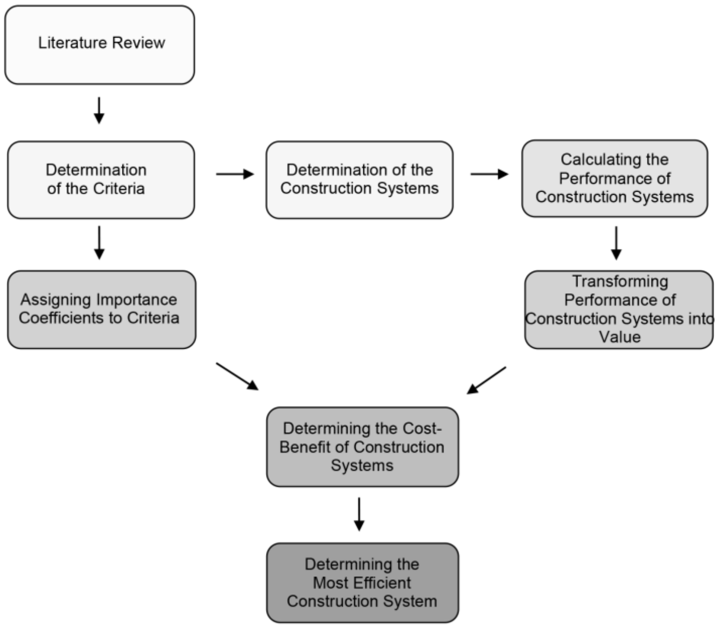


Figure 1. Cost-benefit analysis steps used in research (Öztürk & Savaşır, 2022)

3. Findings and Discussion

Two different architectural projects were prepared with cold-formed steel and RC construction systems. Prof. Dr. Feriha Öz Emergency Hospital was a model for the cold-formed steel structure. It was completed in forty-five days and has 1008 bed capacity. The project was designed and applied with units that repeat each other (Öztürk & Savaşır, 2020). In this research, a unit of the built pandemic hospital was taken as a model, and projects were designed within this framework. The net usage area in the projects for both construction systems has been determined as 135 sqm as in the model hospital. With the help of these projects, the bill of quantity was taken, the cost was determined, and the construction time was obtained with the help of the bill of quantity.

In addition to cost and time that can be determined by mathematical calculations, criteria such as mechanical ventilation and spatial flexibility, which can be given values with the help of questionnaires, have also been determined. Benefit values are obtained with the importance coefficients given to the criteria. With these data, comparisons and evaluations can be made cost-benefit analysis.

3.1. Architectural Projects

Architectural projects were designed with two construction systems within the scope of the research. The pandemic hospital is one story. Technical information about RC construction and CFS construction systems is given.

3.1.1. Reinforced Concrete Construction System

As a result of the research conducted in the world and Turkish literature, the RC construction system was not preferable in the design of the pandemic hospital. However, the RC construction system is one of the two construction systems included in the research. This is because, more than %90 of the structures built regardless of their function, are RC construction.

As in the plans of Prof. Dr. Feriha Öz Emergency Hospital, built in Istanbul during the Covid-19 period and used as a model. There is the same foundation system for both construction systems. The foundation design is a raft foundation. For the most efficient foundation design, the ideCAD program calculated the data to carry the maximum load (Taşdelen, M. personal communication, December 20, 2022). While comparing the construction systems, the calculations of the structure's foundation were not included in the cost and construction time. The same raft foundation was designed for both. Because it is a comparison, it does not affect the result. The unit comprises four patient rooms, four buffer zones and a corridor connecting all these spaces (Figure 2).

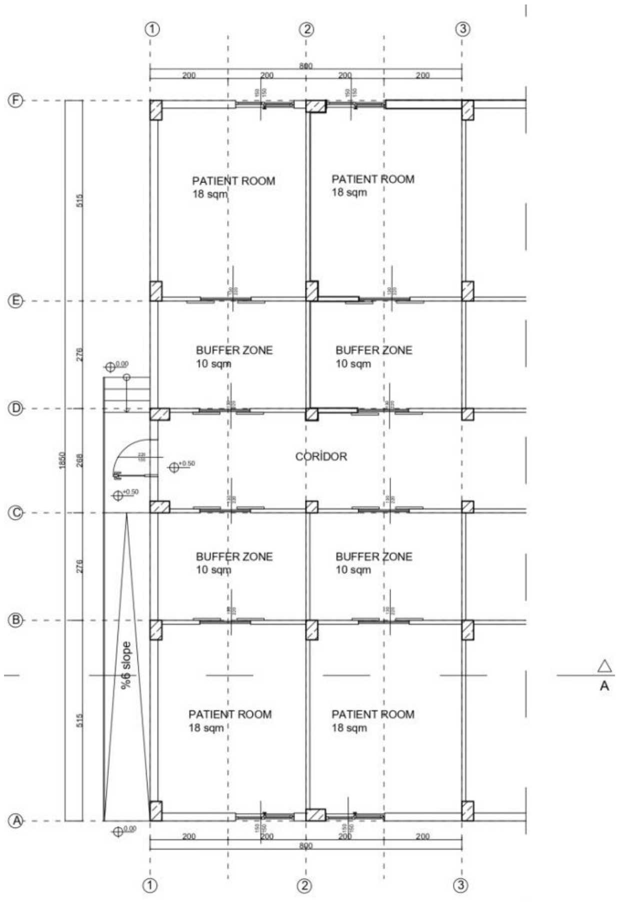


Figure 2. Floor plan of the project

3.1.2. Cold-Formed Steel (CFS) Construction System

Prof. Dr. Feriha Öz and Prof. Dr. Murat Dilmener, two emergency hospitals were built and opened on May 29 and May 31 (Öztürk & Savaşır, 2020). The CFS system is the construction system of both hospitals and has been included in the research within this framework. In this research, the hospital built in Istanbul was a model for the structure designed with a CFS system. Both designs used the same foundation system. The unit comprises four hospital rooms, four buffer zones and a corridor connecting all these spaces (Figure 3).

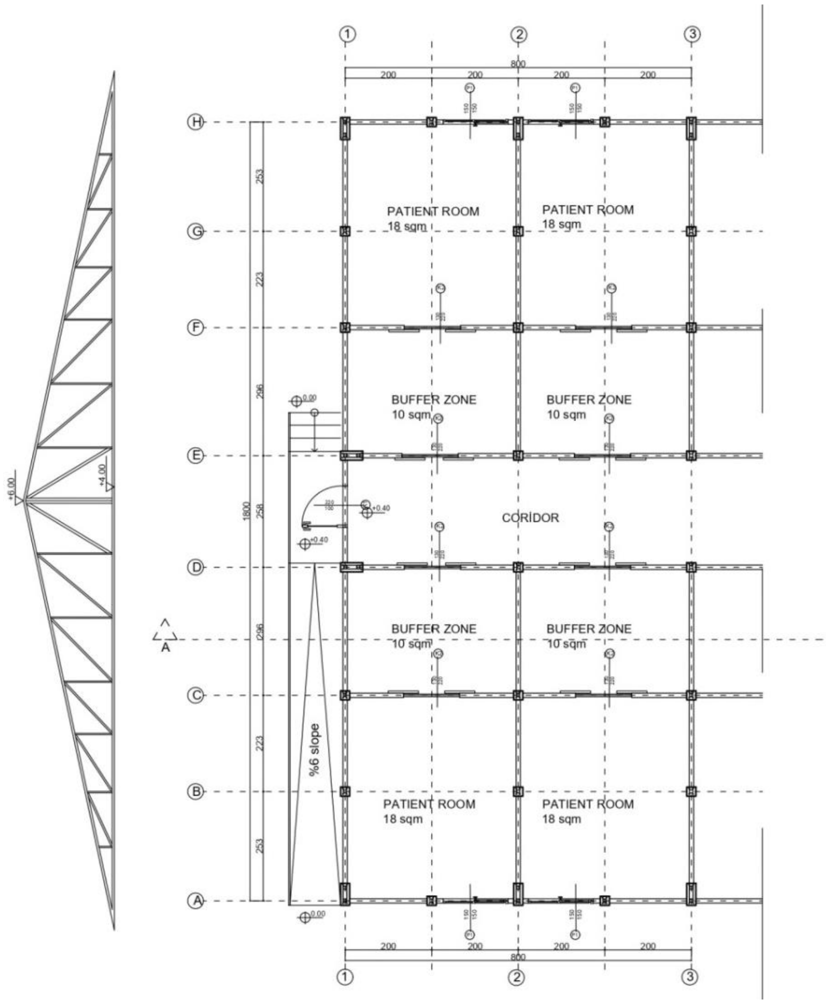


Figure 3. Floor plan of the project

3.2. Criteria (C)

While examining the world and Turkish literature, the similarities and differences between the applied construction systems were investigated. Considering the pandemic situation, the construction systems were compared. At this stage, it has been seen that different construction systems are advantageous or disadvantageous based on different factors. For example, CFS construction is faster to build than RC construction. These factors constitute the 'criteria' within the framework of the research. As mentioned in Chapter 2, a criterion such as the cost, which tangible results can be obtained, has been determined. At the same time, the criteria, which have been converted into concrete values after obtaining results with abstract expressions, have also been determined. In addition, sub-criteria have been created for more efficient evaluation of some main criteria. These criteria are 'twelve' in the research (Table 1).

Determination of criteria is based on construction systems and building materials. The positive aspects of materials and construction systems were analysed. Since the positive properties of some materials are negative compared to others, a holistic research has emerged. Information has been compiled. In this context, Savaşır (2008) compiled the criteria with this method in his thesis. By combining all this information, twelve criteria were created. Determination of these criteria also has significant impact on this research. As an example, construction time is inevitable criterion. In pandemic situation, it is significant to build a hospital rapidly. So, construction systems and its materials that can be constructed quickly are more advantageous.

Table 1. 'Main Criteria' determined within the framework of cost-benefit analysis

Criteria	
C_1: Construction Time	C_7: Ease of Instalment
C_2: Construction Cost	C_8: Ease of Transport of Building Material to and from Construction Site
C_3: Suitability For Sustainable Architecture	C_9: Production Prevalence of Building Elements
C_4: High Sound Insulation Capacity	C_{10}: High Natural Lighting Capacity
C_5: High Thermal Insulation Capacity	C_{11}: Suitability for Disassembly and Reassembly
C_6: Mechanical Ventilation System	C_{12}: High Spatial Flexibility Capacity

3.3. Importance Coefficients

The importance coefficients (IC) were determined by considering the importance levels after the criteria were determined. As mentioned in Chapter 2, a survey was conducted with architects, civil engineers and contractors to determine the coefficients. Architects and civil engineers include both academicians and the private sector. It was emphasized to the questionnaire respondents that the pandemic conditions should be considered when determining the importance of the criteria.

The results were evaluated by considering occupational groups separately. Architects constitute 40% of all responders. For this group, the same results are obtained compared to the whole responders. Civil engineers constitute 40% of all responders. Also this group, the same results are obtained compared to the whole responders. Contractors constitute 20% of all responders. Also this group, the same results are obtained compared to the whole responders. So, the number of questionnaire respondents has been determined as 100. As the number of people increases, the sensitivity of the IC increases. However, there are minimal changes in the IC after a particular value. If this value is less than 100 people, there is a risk that accurate results will not be obtained since it will appeal to a very small number of respondents. It is important to obtain the same results in a survey conducted on people with technical knowledge. This proves the reliability of the results. After the questionnaires, the results were evaluated, the arithmetic average was taken, and the IC was assigned. As a result, the maximum value of 5 was the most important of the 12 criteria determined, and the minimum value of 1 was the least important. The other ten criteria were given relative values according to the results (Table 2).

Table 2. Importance coefficients of each criterion

Importance Coefficient ($1<IC<5$)	**Main Criteria (The most important 4 points, the last 1 point)**
IC_1: **4.42**	C_1: Construction Time
IC_2: **3.18**	C_2: Construction Cost
IC_3: **3.20**	C_3: Suitability For Sustainable Architecture
IC_4: **2.95**	C_4: High Sound Insulation Capacity
IC_5: **3.74**	C_5: High Thermal Insulation Capacity
IC_6: **4.20**	C_6: Mechanical Ventilation System
IC_7: **3.58**	C_7: Ease of Instalment
IC_8: **3.29**	C_8: Ease of Transport of the Building Material to and from the Construction Site
IC_9: **3.51**	C_9: Production Prevalence of Building Elements
IC_{10}: **3.28**	C_{10}: High Natural Lighting Capacity
IC_{11}: **3.54**	C_{11}: Suitability for Disassembly and Reassembly
IC_{12}: **3.18**	C_{12}: High Spatial Flexibility Capacity

3.4. Performance Calculation and Scoring

At this stage, scores were based on criteria considering both construction systems; CFS and RC. There are two types of criteria, main and sub. Sub-criteria were created by detailing the main criteria. The formula in Table 3 calculates each main criterion's value. In this study, twelve main criteria were determined. The formula in Table 3 is used to calculate the value of each main criterion. The formula also includes the importance coefficient and value of the sub-criterion of the primary criterion (Table 3).

Table 3. The formula used within the framework of cost-benefit analysis (Öztürk & Savaşır, 2022)

$$B_j = \frac{\sum_{i=1}^{m}(V_{(i,j)} \times IC_i)}{\sum_{i=1}^{m} IC_i}$$ [j=1,2,…,n; (i=1,2,…,m)]	
B: Benefit of main criteria	IC: Importance coefficient of sub criterion
In this study m=12 (criteria), n=2 (construction systems) was taken.	V: Value of sub criterion

3.4.1. Construction time (C_1)

Different methods were used to obtain the construction times of the two construction systems. For the RC construction system, the unit price list published annually or semi-annually by the Ministry of Environment, Urbanization and Climate Change has been used (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2023). The calculations are based on working times. These times are in the pose numbers, selected according to the work done and the materials used. This way, the Gantt Diagram was created to obtain the total construction time. This study used five-person craftsmen teams, including one carpenter, a cold blacksmith, a concrete worker, a mason and two plasterers (Figure 4). For the comparison, one team of each two systems was used. For the CFS construction system, a proforma invoice was received from the manufacturer based on the designed architectural plan (Figure 5).

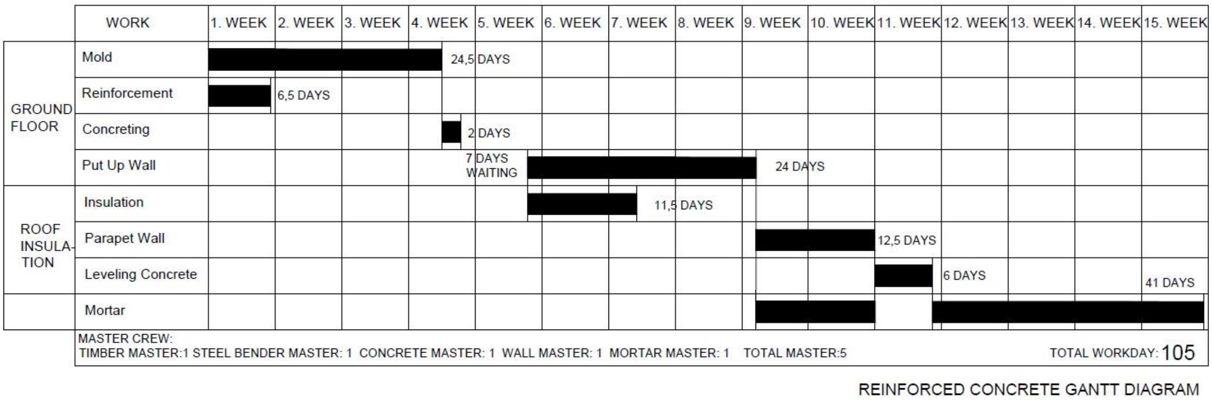
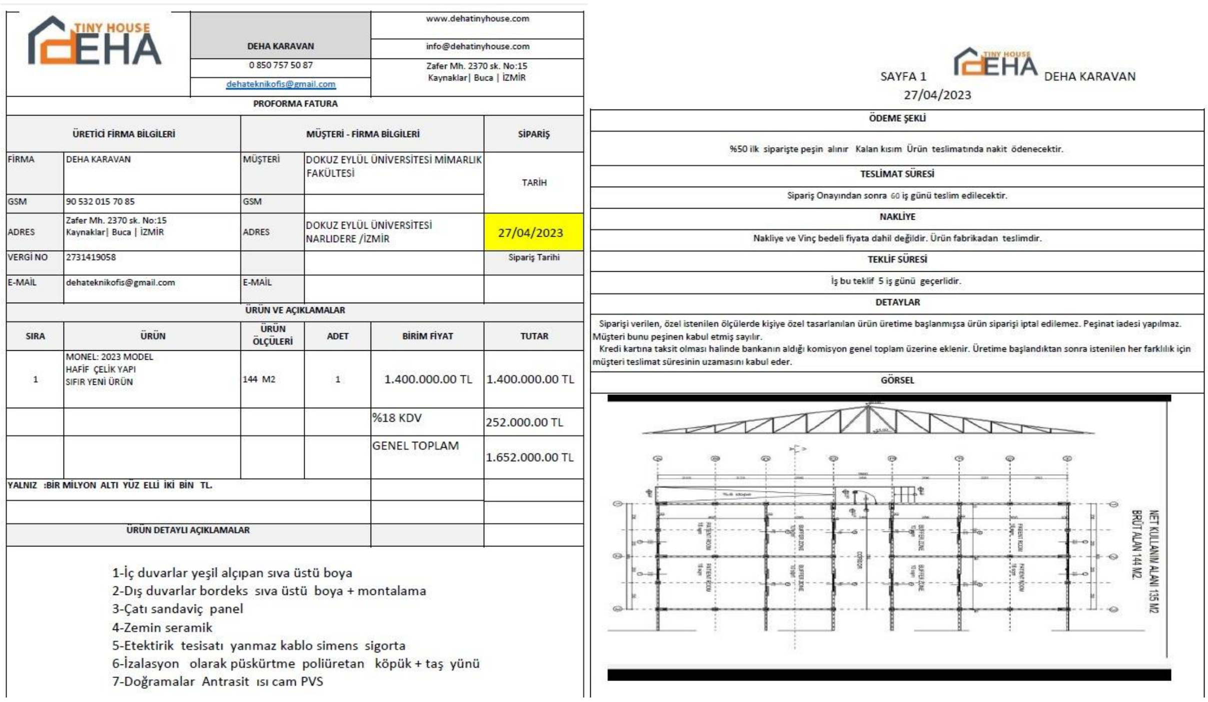


Figure 4. Gantt diagram of reinforced concrete construction



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PROFORMA FATURA

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FİRMA	DEHA KARAVAN	MÜŞTERİ	DOKUZ EYLÜL ÜNİVERSİTESİ MİMARLIK FAKÜLTESİ	TARİH
GSM	90 532 015 70 85	GSM		
ADRES	Zafer Mh. 2370 sk. No:15 Kaynaklar| Buca | İZMİR	ADRES	DOKUZ EYLÜL ÜNİVERSİTESİ NARLIDERE /İZMİR	27/04/2023
VERGİ NO	2731419058			Sipariş Tarihi
E-MAİL	dehateknikofis@gmail.com	E-MAİL		

ÜRÜN VE AÇIKLAMALAR

SIRA	ÜRÜN	ÜRÜN ÖLÇÜLERİ	ADET	BİRİM FİYAT	TUTAR
1	MONEL: 2023 MODEL HAFİF ÇELİK YAPI SIFIR YENİ ÜRÜN	144 M2	1	1.400.000.00 TL	1.400.000.00 TL
				%18 KDV	252.000.00 TL
				GENEL TOPLAM	1.652.000.00 TL

YALNIZ :BİR MİLYON ALTI YÜZ ELLİ İKİ BİN TL.

ÜRÜN DETAYLI AÇIKLAMALAR

1-İç duvarlar yeşil alçıpan sıva üstü boya
2-Dış duvarlar bordeks sıva üstü boya + montalama
3-Çatı sandaviç panel
4-Zemin seramik
5-Etektirik tesisatı yanmaz kablo simens sigorta
6-İzalasyon olarak püskürtme poliüretan köpük + taş yünü
7-Doğramalar Antrasit ısı cam PVS

SAYFA 1 DEHA KARAVAN
27/04/2023

ÖDEME ŞEKLİ
%50 ilk siparişte peşin alınır Kalan kısım Ürün teslimatında nakit ödenecektir.
TESLİMAT SÜRESİ
Sipariş Onayından sonra 60 iş günü teslim edilecektir.
NAKLİYE
Nakliye ve Vinç bedeli fiyata dahil değildir. Ürün fabrikadan teslimdir.
TEKLİF SÜRESİ
İş bu teklif 5 iş günü geçerlidir.
DETAYLAR
Siparişi verilen, özel istenilen ölçülerde kişiye özel tasarlanılan ürün üretime başlanmışsa ürün siparişi iptal edilemez. Peşinat iadesi yapılmaz. Müşteri bunu peşinen kabul etmiş sayılır.
Kredi kartına taksit olması halinde bankanın aldığı komisyon genel toplam üzerine eklenir. Üretime başlandıktan sonra istenilen her farklılık için müşteri teslimat süresinin uzamasını kabul eder.
GÖRSEL

Figure 5. Proforma invoice of CFS construction (Deha Karavan, 2023)

As a result of the Gantt Diagrams, the construction period was 105 days for the RC construction system. For CFS construction system, the proforma invoice received from the manufacturer determined the construction period as 60 days (Table 4). The CFS construction system is %43 faster to build than the RC construction.

Table 4. Comparison of construction time of two systems

Criterion	Construction Systems	
	Reinforced Concrete Construction	Cold-Formed Steel Construction
$C_{1:}$ Construction Time	105 Days	60 Days

3.4.2. Construction cost (C_2)

As the construction period, the construction costs of the two construction systems were obtained by different methods. The stages for the RC construction and bill of quantities were calculated based on the project. The unit price list was from the annual publication by the Ministry of Environment, Urbanization and Climate Change (Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, 2023). In this way, the total construction costs were calculated. For the CFS construction, based on the project, the offer in the proforma invoice received from the manufacturer was used (Figure 5). In order to make an efficient comparison, the 2023 unit price list for the RC construction was used. The manufacturer submitted a bid for the CFS structure according to the current 2023 prices. According to the calculations, the RC construction cost was 711.423.56 Turkish liras (TL), and the CFS construction cost was 1.652.000.00 Turkish liras (TL). The RC construction is %56.8 cheaper than the CFS construction (Table 5).

Table 5. Comparison of the construction costs of two systems

Criterion	Construction Systems	
	Reinforced Concrete Construction	Cold-Formed Steel Construction
$C_{2:}$ Construction Cost	711.423.56 TL	1.652.000.00 TL

3.4.3. Suitability for sustainable architecture (C_3)

In order to determine the value of the main criterion, five sub-criteria were determined. These sub-criteria are in Table 6. First, the importance coefficients of the sub-criteria are assigned by the authors of this study, considering the pandemic conditions and the hospital function. In this process technical evaluations were done, and authors foresaw results. Each was foreseen separately; then an arithmetic average was taken.

Afterwards, comparative values are given for both construction systems. Within the definition of the criterion, a value of '1' is given to the lower performance of the two construction systems. A comparative value is determined for the other construction system (Table 6). Values are determined based on performance for each criterion. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Thus was the valuation process for the main criteria that do not need to create sub-criteria. The values of the first, second and fifth main criteria, such as cost, construction time and thermal insulation criteria, can be reached as concrete data with the help of mathematical calculations. There is no need to create sub-criteria for these main criteria. Giving the comparative values to the sub-criteria, the main criteria values can be determined. Authors foresaw all of the sub-criteria's value after technical evaluations. Also, each was foreseen separately, and then the arithmetic average was taken.

Table 6. Third criterion's value for two systems

Sub-Criteria of the Third Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(3.1)}$- Whether it is harmless to the environment	$IC_{(3.1)}$- 1.0	$V_{(3.1)}$- 1.0	$V_{(3.1)}$- 1.75
$C_{(3.2)}$- Using local material	$IC_{(3.2)}$- 1.25	$V_{(3.1)}$- 1.1	$V_{(3.1)}$- 1.0
$C_{(3.3)}$- Low amount of waste products at the end of the construction process	$IC_{(3.3)}$- 1.0	$V_{(3.1)}$- 1.0	$V_{(3.1)}$- 2.5
$C_{(3.4)}$- Whether the material is reusable after demolition	$IC_{(3.4)}$- 1.0	$V_{(3.1)}$- 1.0	$V_{(3.1)}$- 2.5
$C_{(3.5)}$- Whether the demolition process harms the environment	$IC_{(3.5)}$- 1.0	$V_{(3.1)}$- 1.0	$V_{(3.1)}$- 2.25
Values for Both Systems		V_{R3}- **1.02**	V_{C3}-**1.95**

3.4.4. High sound insulation capacity (C_4)

It is crucial to examine this criterion, especially in the context of a pandemic. To determine the value of the main criterion, three sub-criteria were determined. These sub-criteria are in Table 7. Calculation of the main criteria values was by replacing the values determined in Table 6 in the formula given in Table 3.

Table 7. Fourth criterion's value for two systems

Sub-Criteria of the Fourth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(4.1)}$- Good insulation against external sound	$IC_{(4.1)}$- 1.75	$V_{(4.1)}$- 1.0	$V_{(4.1)}$- 2.0
$C_{(4.2)}$- Good soundproofing between rooms for patient privacy	$IC_{(4.2)}$- 1.0	$V_{(4.1)}$- 1.0	$V_{(4.1)}$- 2.2
$C_{(4.3)}$- Good sound insulation for devices that produce noise by air conduction	$IC_{(4.3)}$- 1.5	$V_{(4.1)}$- 1.0	$V_{(4.1)}$-1.0
Values for Both Systems		V_{R4}- **1.0**	V_{C4}-**1.69**

3.4.5. High thermal insulation capacity (C_5)

Thermal insulation calculations of both construction systems are based on TS 825 'Thermal insulation requirements for buildings' Turkish Standard. In this research, wall sections of both construction systems are examined based on layers. In calculations, the 'thickness' (d) and 'thermal conductivity calculation value' (λ_h) data for each building material used must be known. The 'thermal conductivity calculation value' of the building materials used in the RC construction system is in TS 825. The values of some building materials used in the CFS construction system were obtained from different sources (Dalsan, 2019). The result of the calculations is the 'total thermal transmittance coefficient' (U) value. TS 825 has recommended (U) values according to regions in Türkiye. As mentioned in Chapter 1 because Izmir is in the first region (TS 825 Thermal Insulation Requirements in Buildings, 2008) (Table 8).

Table 8. U values that can be maximum according to regions (TS 825, 2008)

	U_D (W/m^{2}K)	U_T (W/m^{2}K)	U_t (W/m^{2}K)	U_P (W/m^{2}K)
1.Bölge	0.70	0.45	0.70	2.4
2.Bölge	0.60	0.40	0.60	2.4
3.Bölge	0.50	0.30	0.45	2.4
4.Bölge	0.40	0.25	0.40	2.4

The research was in the context of walls, so the critical value is 0.70 in the first region, as highlighted with a red rectangle (Table 8). According to the data obtained, the thermal insulation capacity of RC construction was 1.25 W/m^{2}K, and the thermal insulation capacity of CFS construction was 0.38 W/m^{2}K. The CFS construction has % 69.6 higher thermal insulation capacities than the RC construction (Table 9). The U value of the RC construction system should be max. 0.70. To reach this value, 2 millimetres of XPS material is necessary.

Table 9. Comparison of thermal insulation capacity of two systems

Criterion	Construction Systems	
	Reinforced Concrete Construction (U value)	Cold-Formed Steel Construction (U Value)
$C_{5:}$ High Thermal Insulation Capacity	1.25 W/m^{2}K	0.38.W/m^{2}K

3.4.6. Mechanical ventilation system (C_6)

The sixth criterion is also essential as Covid is an airborne disease. Its spatial design reflects the analysis of a pandemic hospital. For the value of the main criterion requires four sub-criteria. These sub-criteria are in Table 10. The main criteria calculations were by replacing the values determined in Table 6 in the formula given in Table 3.

Table 10. The sixth criterion's value for two systems

Sub-Criteria of the Sixth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(6.1)}$- Problems arising from the construction system encountered during the construction/installation process of the ventilation system	$IC_{(6.1)}$- 2.0	$V_{(6.1)}$- 1.0	$V_{(6.1)}$- 2.75
$C_{(6.2)}$- The negativities brought by the maintenance and repair of the ventilation system to the construction system	$IC_{(6.2)}$- 2.0	$V_{(6.1)}$- 1.0	$V_{(6.1)}$- 2.5
Values for Both Systems		V_{R6}- **1.0**	V_{C6}- **2.62**

3.4.7. Ease of instalment (C_7)

The instalment criterion is also vital during and after the construction of a building that has a hospital function. Renovation works can be done as needed. To examine this criterion, it is essential to analyse it in detail.

To determine the value of the main criterion, two sub-criteria were determined. These sub-criteria are in Table 11. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 11. Seventh criterion's value for two systems

Sub-Criteria of the Seventh Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(7.1)}$- Easy laying of plumbing under construction	$IC_{(7.1)}$- 1.5	$V_{(7.1)}$- 2.75	$V_{(7.1)}$- 1.0
$C_{(7.2)}$- Easy to make plumbing repairs during use	$IC_{(7.2)}$- 1.0	$V_{(7.1)}$- 3.0	$V_{(7.1)}$- 1.0
Values for Both Systems		V_{R7}- **2.85**	V_{C7}- **1.0**

3.4.8. Ease of transport of the building material to and from the construction site (C_8)

The transportation of building materials to the construction site is an important criterion. For example, since the container prefabricated system is the factory's final product, it is difficult to transport on the road due to its huge dimensions. Due to the size of the building materials arriving at the construction site, it may be difficult to transport them within the construction site. There may be insufficient workforce to transport construction materials within the site.

In order to determine the value of the main criterion, five sub-criteria were determined. These sub-criteria are in Table 12. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 12. Eighth criterion's value for two systems

Sub-Criteria of the Eighth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(8.1)}$- Ease of transportation from the production site to the construction site	$IC_{(8.1)}$- 1.5	$V_{(8.1)}$- 1.1	$V_{(8.1)}$- 1.0
$C_{(8.2)}$- Simple to put building materials and components in place	$IC_{(8.2)}$- 1.0	$V_{(8.1)}$- 1.1	$V_{(8.1)}$- 1.0
$C_{(8.3)}$- Difficulty in transporting building components within the construction site due to weight and quantity	$IC_{(8.3)}$- 1.0	$V_{(8.1)}$- 1.15	$V_{(8.1)}$- 1.0
$C_{(8.4)}$- The possibility of damage, deterioration or breakage of the building components during transportation to the construction site or when they are unloaded at the construction site.	$IC_{(8.4)}$- 1.0	$V_{(8.1)}$- 1.0	$V_{(8.1)}$- 1.1
$C_{(8.5)}$- Road transport difficulty due to the dimensions of the components to be transported	$IC_{(8.5)}$- 1.5	$V_{(8.1)}$- 1.75	$V_{(8.1)}$- 1.0
Values for Both Systems		V_{R8}- **1.25**	V_{C8}- **1.01**

3.4.9. Production prevalence of building elements (C_9)

The use of local materials is important because the research was conducted in the context of Türkiye. In case of a pandemic, each country must first use its resources effectively. So the prevalence and capacity of production of building materials in Türkiye is essential. To determine the value of the criterion, two sub-criteria were determined. These sub-criteria are in Table 13. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 13. Ninth criterion's value for two systems

Sub-Criteria of the Ninth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(9.1)}$- Widespread production of building components throughout Türkiye	$IC_{(9.1)}$- 1.0	$V_{(9.1)}$- 2.5	$V_{(9.1)}$- 1.0
$C_{(9.2)}$- High annual production capacity of building components	$IC_{(9.2)}$- 1.25	$V_{(9.1)}$- 2.5	$V_{(9.1)}$-1.0
Values for Both Systems		V_{R9}- **2.5**	V_{C9}- **1.0**

3.4.10. High natural lighting capacity (C_{10})

According to Asyary & Veruswati (2020), it has been determined that natural lighting positively affects the immune system of Covid-19 patients and enables them to recover faster. In this sense, having a high natural lighting capacity is important.

Daylight creates a better visual environment than artificial lighting due to its varying intensity according to the time of day and seasons. It provides a dynamic interior environment and improves the users' experience in visual comfort, aesthetics and space perception. Also, it plays a vital role in promoting human health and well-being (Abidi & Rajagopalan, 2020; Ullah, 2014). Considering these, daylight can be considered as a potential measure in building design to reduce human health risks against the adverse effects of the quarantine process that we are closed (Sipahi & Yamaçlı, 2021).

Only one sub-criterion was determined to find the value of the main criterion. This sub-criterion is in Table 14. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 14. Tenth criterion's value for two systems

Sub-Criteria of the Tenth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(10.1)}$- The window can be opened at the desired rate for natural lighting	$IC_{(10.1)}$- 1.25	$V_{(10.1)}$- 2.75	$V_{(10.1)}$- 1.0
Values for Both Systems		V_{R10}- **2.75**	V_{C10}- **1.0**

3.4.11. Suitability for disassembly and reassembly (C_{11})

This criterion is an important criterion that should be examined for sudden, unexpected processes such as pandemics. To determine the value of the main criterion, two sub-criteria were determined. These sub-criteria are in Table 15. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 15. Eleventh criterion's value for two systems

Sub-Criteria of the Eleventh Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(11.1)}$- Being a system that can be installed and applied easily and in a short time	$IC_{(11.1)}$- 1.0	$V_{(11.1)}$- 1.0	$V_{(11.1)}$- 3.0
$C_{(11.2)}$- Temporary structures designed for temporary periods such as pandemics	$IC_{(11.2)}$- 1.0	$V_{(11.1)}$- 1.0	$V_{(11.1)}$-3.0
Values for Both Systems		V_{R11}- **1.0**	V_{C11}- **3.0**

3.4.12. High spatial flexibility capacity (C_{12})

Since the pandemic is sudden, the need for space must be met urgently. Therefore, idle structures with different functions can be converted into pandemic hospitals (Öztürk & Savaşır, 2020). At the same time, additions can be made to the hospital structure as the process progresses. Therefore, spatial flexibility is an important criterion that needs to be examined. To determine the value of the main criterion, two sub-criteria were determined. These sub-criteria are in Table 16. Values for the main criteria are calculated by replacing the values determined in Table 6 in the formula given in Table 3.

Table 16. Twelfth criterion's value for two systems

Sub-Criteria of the Twelfth Main Criterion	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
$C_{(12.1)}$- In case of being permanent, it is appropriate to use it with a different function.	$IC_{(12.1)}$- 1.5	$V_{(12,1)}$- 1.0	$V_{(12.1)}$- 1.5
$C_{(12.2)}$- Since it is created with a modular system, it can provide integration in case of adding or removing from the structure.	$IC_{(12.2)}$- 1.0	$V_{(12.1)}$- 2.25	$V_{(12.1)}$-1.0
Values for Both Systems		V_{R12}- **1.5**	V_{C12}- **1.3**

Importance coefficients and values of twelve main criteria created in comparing light steel and RC construction systems were determined. A Gantt chart was created for the first criterion, the construction time and a proforma invoice was received. In the context of the obtained mathematical data, it has been concluded that the CFS construction system can be applied 43% faster than RC. For the second criterion, cost, quantities with unit prices were calculated, and proforma invoices were received. The results showed that the RC construction system was 56% less costly than CFS. Within the scope of the third criterion, sustainability, it was concluded that the CFS construction system is 91% more sustainable than RC. For the fourth criterion, the sound insulation capacity, it has been determined that the CFS construction system is 70% better than the RC. For the fifth criterion, the thermal insulation capacity, it was determined that the CFS construction system was 69% better than the RC. The CFS construction system is 162% more advantageous than RC for mechanical ventilation, the sixth criterion. The RC construction system is 185% more advantageous than CFS for the installation system, which is the seventh criterion. The RC construction system is 24% more advantageous than CFS for transporting the building elements, the eighth criterion. For the ninth criterion, the prevalence of production, it was determined that the RC construction system was 150% more advantageous than CFS. The RC construction system is 175% more advantageous than CFS for natural lighting, the tenth criterion. The CFS construction system is 200% more advantageous than RC for the eleventh criterion, disassembly and reassembly. The RC construction system is 15% more advantageous than CFS for spatial flexibility, the twelfth criterion (Table 17).

The benefits of both construction systems are found separately according to the formula in Table 3. In this context, as stated in Section 3.4, criteria, construction systems, importance coefficients, and values are the elements needed for the calculation. As a result of all these processes, the benefit of the RC construction system was 1.52. In contrast, this benefit was 1.58 for the CFS construction system. When the benefits of these two construction systems are compared, the CFS construction system is approximately 5% more effective than the RC construction system (Table 17).

Table 17. Benefits of the construction systems

Main Criteria	Importance Coefficients of Sub-Criteria	Values of Sub-Criteria	
		Reinforced Concrete Constr.	Cold-Formed Steel Constr.
C_1: Construction Time	IC_1- **4.42**	V_{R1}- **1.0**	V_{C1}- **1.43**
C_2: Construction Cost	IC_2- **3.18**	V_{R2}- **1.56**	V_{C2}- **1.0**
C_3: Suitability For Sustainable Architecture	IC_3- **3.20**	V_{R3}- **1.02**	V_{C3}- **1.95**
C_4: High Sound Insulation Capacity	IC_4- **2.95**	V_{R4}- **1.0**	V_{C4}- **1.69**
C_5: High Thermal Insulation Capacity	IC_5- **3.74**	V_{R5}- **1.0**	V_{C5}- **1.69**
C_6: Mechanical Ventilation System	IC_6- **4.20**	V_{R6}- **1.0**	V_{C6}- **2.62**
C_7: Ease of Instalment	IC_7- **3.58**	V_{R7}- **2.85**	V_{C7}- **1.0**
C_8: Ease of Transport of Building Material to and from Construction Site	IC_8- **3.29**	V_{R8}- **1.25**	V_{C8}- **1.01**
C_9: Production Prevalence of Building Elements	IC_9- **3.51**	V_{R9}- **2.5**	V_{C9}- **1.0**
C_{10}: High Natural Lighting Capacity	IC_{10}- **3.28**	V_{R10}- **2.75**	V_{C10}- **1.0**
C_{11}: Suitability for Disassembly and Reassembly	IC_{11}- **3.54**	V_{R11}- **1.0**	V_{C11}-**3.0**
C_{12}: High Spatial Flexibility Capacity	IC_{12}- **3.18**	V_{R12}- **1.5**	V_{C12}- **1.3**
Benefits of the Construction Systems		**B_R- 1.52**	**B_C- 1.58**

4. Conclusion and Suggestions

Within the scope of the architectural project developed within the framework of the prepared scenario, two construction systems were compared within the framework of twelve criteria. According to the analysis results obtained in Table 17, while the RC construction system is more advantageous for six criteria out of twelve, the CFS construction system is more advantageous for the other six criteria.

Among the twelve criteria, the three criteria with the highest importance coefficient are construction time, mechanical ventilation and thermal insulation capacity. Importance coefficients take values between 1 and 5 in this article. Construction time and mechanical ventilation are the criteria with more than 4 importance coefficients. The CFS construction system is more effective and suitable than the RC for these three criteria, with the highest importance coefficient. The three criteria with the lowest importance coefficient are sound insulation capacity, spatial flexibility and construction cost. Only the sound insulation criterion was below 3 as an importance coefficient among all the criteria. The other least critical criteria were spatial flexibility and cost, with importance coefficients slightly above 3. The RC construction system was more effective and suitable for these three least important criteria than CFS construction. The other six criteria have significance levels between 3.58 and 3.20. In conclusion, RC construction was more effective for four criteria, and CFS construction was more effective for two criteria.

Among the 12 criteria, the RC construction system in six criteria and the CFS construction system in six criteria received higher importance coefficients. However, since each criterion is not equally important, there is no equality between the construction systems. At this point, the conditions for determining the importance coefficients are adequate. The framework of this article took the pandemic situation and hospital design factors into account. The significance levels of the coefficients have been evaluated in this context.

The total success scores of both construction systems, which were reached as a result of the calculations, were compared. While the benefit of the CFS construction system was 1.58, the benefit of the RC construction system was 1.51. With an average of 5% difference, the CFS construction system is the more efficient construction system. 5% difference is an important result. In the research, a feasibility study is being carried out on two construction systems.

Feasibility means that it is the analysis of the economic, technical and financial probability of investment projects that will provide long-term benefits (Aydın et al., 2018). As a result, if an alternative is more advantageous than the other, it is more preferable. The result achieved is important because every country must use its resources most efficiently.

In this scenario, the conclusion is that it would be more efficient to construct the CFS structure. As it is known, the CFS construction system was preferred in Türkiye during the COVID-19 pandemic in the recent past. The results of this research show parallelism with this situation. The technical results obtained with the comparisons made within the framework of this article support the application of the pandemic hospital in Türkiye.

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The first author contributed %60 and the second author contributed %40 to the article. We declare that there is no conflict of interest.

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