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Research Article

Evaluation of the Environmental Impact of Formwork Systems Depending on the Service Life and Cost Analysis

Ebru Kılıç Bakırhan, Merve Tuna Kayili*

Başak Cengiz Faculty of Architecture, Karabuk University, Karabuk, Turkey

Keywords

Formwork systems, Service life, Environmental impact assessment, Cost analysis.

Abstract

The energy consumption and carbon emissions caused by building materials on a global scale highlight the importance of material selection, especially in the frequent use of formwork materials in the construction industry. The service life of these materials and the environmental effects of planning based on their use are critical factors. The selected materials' service lives directly affect the total amount of planned material for construction, and this is responsible for a series of carbon emissions throughout the materials' life cycle. In this study, four different formwork materials were evaluated in terms of their environmental impact and cost within the scope of a mass housing project, considering their service lives. The results of the study revealed that, when the service lives of the materials were considered equal, the carbon emission value of the steel formwork system was 19 times higher than that of the traditional timber formwork system. However, when the service lives were not considered equal, this situation was completely reversed, and it was determined that the traditional timber system had 60.6% more global warming potential than the steel formwork panel system. The fact that metal formwork systems cause less environmental impact due to their longer service lives reveals how important service life and reuse are in determining the environmental performance of materials. When the materials were evaluated in terms of cost, it was concluded that the traditional timber formwork system would be more economical for a single house (96.3% more cost-effective compared to the steel formwork system), and the steel panel formwork system would be more economical for mass housing projects (70% more cost-effective compared to the traditional timber formwork system).

1. Introduction

The increase in urban population has led to a rise in the number of buildings. According to the United Nations, the world population is expected to reach 9.8 billion by 2050, and as a result, the number of buildings in the world is projected to increase from 100 million to 2.6 billion [1]. Tunç [2] reported that in Turkey, the total number of buildings increased by 48% between 2000 and 2020, and this increase is expected to reach 80% by 2050 and 87% by 2080.

As Huang [3] indicated, in parallel with the increasing number of buildings globally, the consumption of building materials in the construction sector has almost tripled, from 6.7 billion tons in 2000 to 17.5 billion tons in 2017. This increase in the consumption of building materials over time underscores the importance of choosing the right building materials, especially during the design phase [4, 5, 6, 7].

According to Li [8], the desire for high-speed construction has led to the use of reinforced concrete systems, and the formwork materials required by these

* Corresponding Author: Merve Tuna Kayılı
E-mail address: archmervetuna@gmail.com, ORCID: https://orcid.org/0000-0002-3803-8229

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systems have a high share of use in the construction sector. Deshmukh and Shalgar [9] specified that formwork systems, which help fresh concrete to take the desired shape and are installed and then dismantled to ensure that the concrete gains the necessary strength, were first constructed using wooden elements. Hansen [10] stated that due to the ease of use provided by metal-framed materials such as aluminum, metal formwork systems have taken their place in the sector over time.

In addition to the advantages and disadvantages that wood and metal formwork systems have (as shown in Table 1), it is also necessary to consider the cost, duration of the project, and the quality of production when choosing a formwork system type, as formwork systems account for most of the costs incurred during the formation of reinforced concrete structures [8]. In the study by Zohaib [11], which compared timber and steel formwork systems in terms of quality, cost, and construction speed, the unit cost per square meter of steel was found to be approximately 22.5% higher than that of timber formwork. However, considering the quality and construction speed required for a smooth concrete surface, steel performs better than timber.

Asadi & Praneeth [12] conducted a study evaluating a real-time project in India in terms of cost, speed, quality, and frequency of use. It was reported that although the aluminum formwork system requires a high cost, it reduces the total cost if it is used several times. In addition, the aluminum formwork system can be completed faster than the traditional timber formwork system. However, due to the standardized dimensions of the aluminum formwork system, the traditional timber formwork may be more advantageous in cases where changes are required.

Table 1. Comparison of timber and metal formwork systems [8, 10, 13, 14]

	Timber formwork	**Metal formwork**
Advantages	Lightweight. Many variations can be produced from the standard unit. More economical and easy to implement for small-scale projects. They can be used to create curved surfaces. Emission rate is low thanks to the ability of carbon storage	It has faster installation, dismantling, and re-installation stages compared to timber. It has the possibility of long-term use. Reduces costs thanks to multi-use function. Surface smoothness is high. Although it is more suitable for flat surfaces, it can also be used for curved surfaces. It is more appropriate to use in long-span structures. It saves cost and time by being converted into a permanent formwork element with proper design. Aluminum is more economical and lighter than steel
Disadvantages	Short lifespan They can only be reused in structures with similar geometry. They become unusable as a result of not being able to return to their original state under high pressure. Labor and time consumption for the installation of the elements is high, especially for high-rise buildings.	Expensive Requires extra support elements due to its own weight. Extends the curing time of concrete in cold weather. It can affect the durability, strength, and surface quality of concrete by causing dust in rainy seasons. Since aluminum can interact with concrete, it should be used as an alloy. Not appropriate for use in complex shapes.

In addition to criteria such as speed, quality, and cost sought in building materials, the environmental effects of the materials used in formwork systems should not be ignored. Grant & Ries [15] assert that the environmental effects caused by the materials during their lifetime are closely related to the longevity of the selected material. Gaspar & Santos [12] suggest that materials with a long service life reduce energy and resource consumption, ensuring lower emissions. For example, materials such as steel, which have high embodied energy intensity [14] and high initial cost [17], can be more advantageous in terms of carbon emissions and cost thanks to their multiple usage possibilities.

In a study conducted by Donkor and Mahamud [18], the most frequently used timber and steel formwork systems were evaluated in Northern Ghana by using a survey performed with 80 participants in the construction industry. The results of the study revealed that although steel systems were considered more appropriate for most projects, timber systems were preferred more due to the high cost of steel systems. According to Mahesh et al. [19], however, contrary to popular belief, the cost of steel formwork systems is not much different from the cost of timber formwork systems. Even in some projects, formwork systems created with timber materials require higher investments. Therefore, it is crucial for contractors to evaluate formwork systems according to their lifetime and to consider life-cycle costs rather than initial costs.

In a study by Yip [20], where formwork systems were discussed in terms of cost, working time, and structural waste generation within the scope of two school projects in Hong Kong, it was concluded that composite formwork produced less waste. It was indicated that composite formwork systems are more economical, considering their reuse in similar projects. Although Hill and Norton [21] specified that timber allows atmospheric carbon to be stored for a long time, due to its short lifespan, it may cause increased wood production and thus deforestation and environmental damage according to Lo [22]. In a study where the environmental effects of timber and plastic formwork systems were investigated in Taiwan, it was determined that the formwork system obtained from recycled plastic waste caused approximately 3% less CO2 emissions per year than the traditional timber formwork system [22].

While most studies on formwork systems have examined factors such as work quality, speed, and cost [11, 12, 18], there are some studies on the wastes caused by formwork systems [20] and emissions [22]. However, there are not enough studies investigating which system is more advantageous to minimize the damage to the environment in the case of applying different formwork system types in a single building or mass housing projects. On the other hand, since service lives of formwork materials vary greatly, life cycle evaluation of these systems is of great importance in terms of reducing global emissions, considering their heavy usage rate on a sectoral basis. Traditional timber formwork systems can be thought to have less environmental impact than other formwork systems due to their carbon absorption properties throughout their life cycles. However, metal formwork systems may exhibit superior performance compared to traditional timber systems in terms of environmental impact when their service life is considered. In this context, this study aims to compare timber and metal formwork systems in terms of environmental impact and cost by considering their service life and to evaluate the optimal decisions within the scope of single and multiple dwellings. The study is expected to guide decision-makers, architects, and construction experts on formwork systems.

2. Materials and Methods

2.1. Case Study

In the study, the Sarıyaprak Municipality in the Besni district of Adıyaman province was chosen as the project area. The Type 1 regional architectural project, which was prepared for Adıyaman as part of the Turkish Ministry of Environment, Urbanization, and Climate Change, was deemed suitable as an architectural project to be transformed into mass housing.

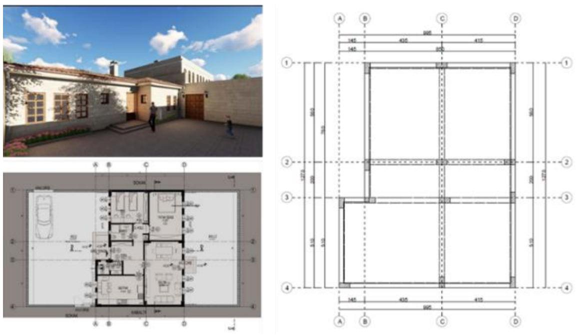

Figure 1. Schematic floor plan [23] and structural system application plan of the case study (Adapted from [23])

The designed building had a single story, a floor area of 111.5 m², and a reinforced concrete skeleton. This study aimed to determine the environmental performance and initial investment costs of four different formwork systems that could be used during the construction of the selected type of project within the scope of a mass housing project consisting of 500 residences. The plan schemes and visuals of the project are presented in Figure 1.

2.2. Traditional Timber Formwork System

Wood is the primary material used in traditional timber formwork systems. To install the traditional timber formwork system, images taken during formwork installation in surrounding constructions and various documents were used (Figure 2). While the formwork systems were modeled in the Revit program, 10 mm thick timber was used as the surface material that held the column and floor concrete. Additionally, 3x10 cm and 5x10 cm laths, as well as 10x10 cm planks, were used as the carrier element for the columns and flooring, respectively. The flooring elements were placed every 100 cm on the X-axis and every 30 cm on the Y-axis (Figure 3).

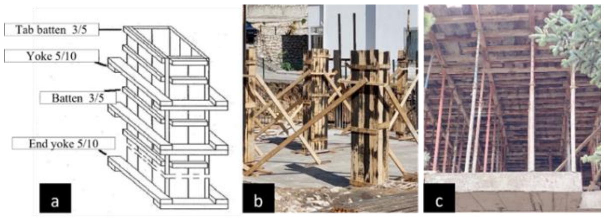

Figure 2. Traditional timber formwork system: (a) column formwork elements [24], (b) column formwork manufacturing, (c) slab formwork manufacturing

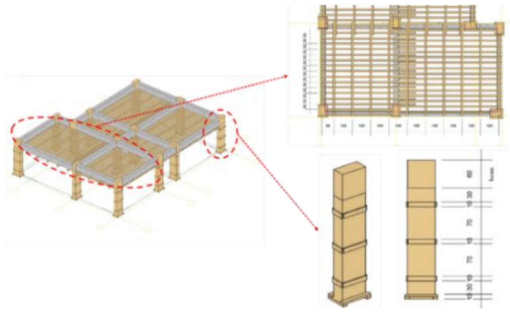

Figure 3. The details of the traditional timber formwork system

2.3. Formwork Systems Created with Industrial Timber

The main material of the industrial timber formwork system is phenolic film-coated plywood. To model this system in 3D, the Peri plug-in for Revit was used. The formwork system was created by placing the elements already present in the add-on to the floors and columns in the dimensions specified in the figures below. Plywood acts as a concrete holding surface in this system, and H20 beams are used as support elements to hold this surface material. In this system, the beams of the floor are placed approximately 150 cm apart on the X-axis and 35 cm on the Y-axis.

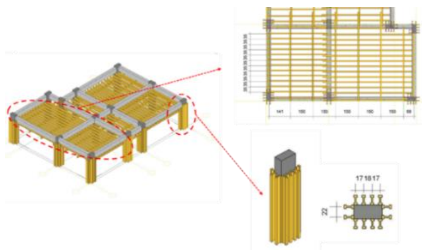

Figure 4. The details of the traditional timber formwork system

2.3. Formwork Systems Created with Metal Materials

Steel and aluminum are the main materials of metal formwork systems. To model this system in 3D, the Peri plug-in for Revit was used. Panel systems with standard dimensions are used for floors and columns in steel and aluminum formwork systems (Figure 5).

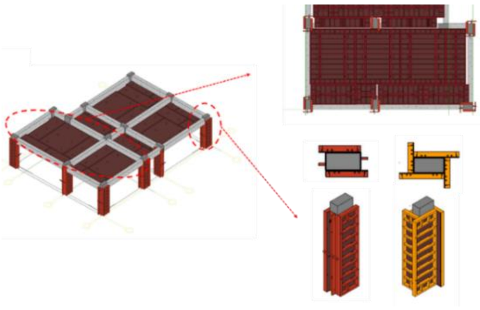

Figure 5. The details of metal (aluminum and steel) formwork systems

2.4. Method

The life cycle assessment (LCA) method was used to determine the environmental impact values by considering the service lives of the formwork systems used in the selected mass housing project. LCA-related studies, including building materials [4, 25], building components [14, 26], and whole structures [27, 28], have almost doubled in recent years.

Table 2. Environmental impact classes evaluated within the scope of LCA EN-15978 method

Impact class	Unit	Definition
Global warming potential (GWP)	kgCO_2 eq	Carbon footprint, Global temperature rise due to the increase in greenhouse gases
Acidification potential (AP)	kgSO_2 eq	Gases that dissolve easily in water, such as CO_2, cause acidification in the oceans
Eutrophication potential (EP)	kgPO_4-eq	The emergence of the dominant species with the increase of minerals in the soil and water endangers the life of other species
Ozone depletion potential (ODP)	kgCFC$_{11}$eq	Corrosion of the ozone layer, which filters out harmful UV rays
Photochemical ozone creation potential (POCP)	kgC_2H_4eq	Photochemical fog formation, summer smoke
Primary energy use (MJ)	MJ	Primary energy consumption for the manufacturing process of the building material

The LCA method requires a large database, and in this study, the One-click LCA plugin, which can be added to the Revit program, was used. The system boundaries were determined as A1-A3 (material) and A4 (transport) phases, and the functional unit was chosen as 1 kg for support elements and 1 m^2 for surface elements.

The production process of the main formwork materials is shown in Figure 6. For environmental impact assessment, the environmental impact classes proposed by the LCA EN-15978 method were used (Table 2).

Two scenarios were created, one in which the service lives of the formworks were taken into account and one in which they were not. The required amount of formwork material was determined based on the scenarios created, and environmental impact values were calculated by One-Click LCA. Additionally, the cost analysis of the formwork systems required for both a single house and mass housing project was conducted (Figure 7).

2.5. Assumptions and Scenarios

In the context of the study, environmental impact values varying based on formwork materials were examined by using 4 different formwork systems (traditional timber, industrial timber, steel, and aluminum) in the construction of 500 houses, and cost analysis was made. While constructing the column-beam system of the houses, only the surface elements created for pouring concrete in each formwork system and the support elements holding this surface were taken into consideration. The accessories and anchor elements were not considered within the scope of the study.

The environmental impact values depending on the service life of the materials were evaluated over two different scenarios. The “wear-out coefficient” used to describe the second scenario was obtained using Eq. (1) It should be noted that as the wear-out coefficient decreases, the number of uses of the materials increases.

$$S\lambda = \Sigma h / f \quad (1)$$

where Sλ: Coefficient of wear-out, Σh: Total number of the buildings, f: Frequency of use

SC_{01}: In Scenario 1, it was assumed that the wear-out coefficient was the same for each formwork system. Environmental impact assessments of the materials were made in terms of functional units within the scope of this scenario, but their service lives were ignored.

SC_{02}: In Scenario 2, the total amount of material required for one house was determined for each formwork system type, and the "wear-out coefficients" required for 500 houses were calculated, taking into account the service lives of the materials (Eq.1 and Table 3). Additionally, it was assumed in this scenario that the construction of another structure could not begin until the construction of a building was completed. Calculations were made considering that the same formwork elements could be used for other structures. For both scenarios, the selection of material supply points was prioritized based on proximity to Sarıyaprak Municipality, the project area, to reduce the impact of the A4 phase. While a sawmill near Adıyaman city was chosen for traditional timber formwork materials, the production facility closest to the project area was selected from Gaziantep for other formwork systems. However, since the materials required for these formwork systems were produced in Sakarya rather than Gaziantep, the distance between Sakarya and Gaziantep was also included in the transportation distance to be considered (Table 3).

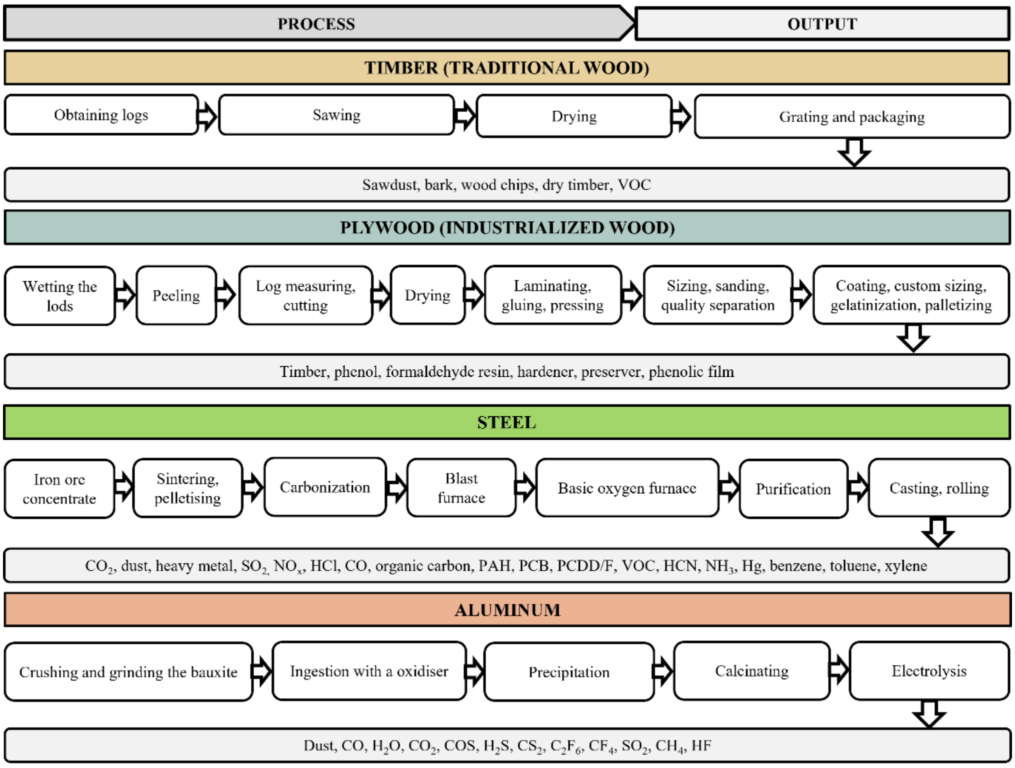

Figure 6. Formation stages of the main materials used in formwork systems [29, 30, 31, 32, 33, 34]

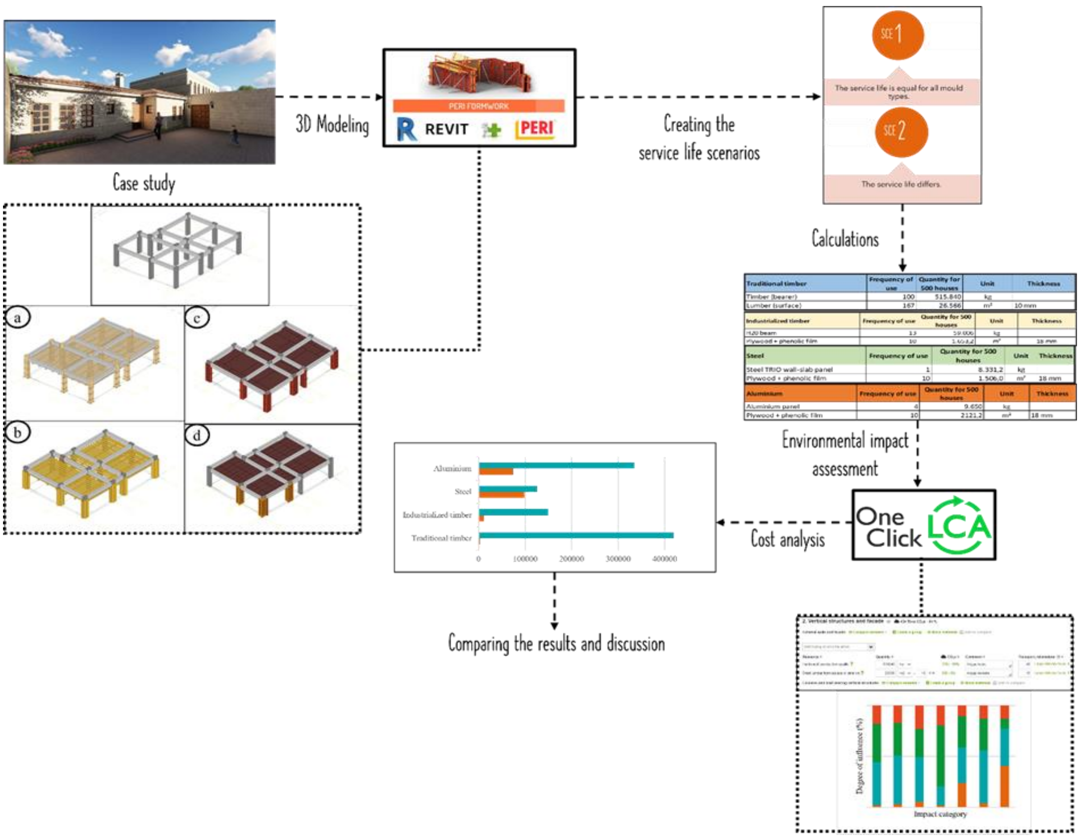

Figure 7. Workflow chart

The unit of support materials used in the formwork systems was taken as kg while the unit of surface materials was taken as m² and a table of quantities was generated (Table 5).

Table 3. Frequency of use and wear-out coefficients of the formwork materials [9, 10, 24, 35, 36]

Formwork System	Material	Frequency of Use (times)	Wear-out Coefficient for SC_{02}	Company Name and Distance to the Project Site
Traditional timber	Timber plank (support)	5	100	Kandırmaz Lumber, Gölbaşı/Adıyaman 45 km (production and distribution)
	Lumber (surface)	3	167	
Industrialized timber	H20 beam (support)	40	13	Peri Sakarya Scaffold and Formwork Production(factory), Hendek/Sakarya: 983 km
	Plywood (surface, 18 mm)	50	10	
Steel panel	Steel panel (support)	500	1	Peri Sakarya Scaffold and Formwork Engineering (distributor), Şehitkamil/Gaziantep: 85 km
	Plywood (surface, 18 mm)	50	10	
Aluminum panel	Aluminum panel (load-bearing)	150	4	
	Plywood (surface, 18 mm)	50	10	

The amounts and unit prices of the materials are listed in Table 4. The costs of the materials were converted to the exchange rate based on the indicative Central Bank Rates of Turkey, established on May 27, 2022, at 15:30, and 1 Euro was assumed to be worth 17.52 TL [37]. When converting from kilograms to volume (m³), the unit volume weight was taken as 800 kg/m³ for plywood and 600 kg/m³ for coniferous timber [38]. For SC_{01}, 500 times the amount of formwork material required for one house was considered for each formwork system type. For SC_{02}, the wear-out coefficients provided in Table 3 were taken into account for each formwork system type. Based on this, when comparing SC01 and SC_{02}, it was determined that traditional timber formwork system benefited 3-5 times less from material recovery due to the reuse of materials. It was observed that the amount of support and surface materials in industrial timber, steel, and aluminum formwork systems achieved a gain of 38-50 times, 500-50 times, and 115-50 times, respectively.

Table 4. Quantity and unit cost list of materials (prices include taxes)

Material	Single house	SC_{01}	SC_{02}	Unit	Unit Price (€)
Plank	8.6	4,299	860	m³	314
Lumber	2.9	1,432	478	m³	
H20 beam	771	385,500	10,023	m	12
Plywood	3	1,488	29.8	m³	1000
Steel panel	179	89,500	179	m²	550
Plywood	2.7	1,355	27.1	m³	1000
Aluminium Panel	212	106,000	848	m²	350
Plywood	3.8	1,909	38.2	m³	1000

Table 5. The amount of materials used in the formwork systems

	Amount (Single house)	Amount (SC_{01}/500 houses)	Amount (SC_{02}/ 500 houses)	Unit
Traditional timber				
Plank (support)	5,158	2,579,200	515,840	kg
Lumber (surface)	159	79,540	26,566	m²
Industrialized timber				
Phenolic film-coated plywood produced from birch	4,539	2,269,450	59,006	kg
Plywood (18 mm)	165.3	82,660	1,653	m²
Steel panel				
Metal sheet (100% recyclable)	8,331	4,165,580	8,331	kg
Plywood (18 mm)	151	75,300	1,506	m²
Aluminum panel				
Aluminum sheet (100% recyclable)	2,227	1,113,468	9,650	kg
Plywood (18 mm)	212	106,060	2,121	m²

3. Results and Discussion

3.1. Environmental Impact Assessment

When examining SC_{01}, it was found that the industrial timber formwork system had the highest effect value in the A1-A3 phase (Figure 8). Since service life was ignored and each material was used only once in this scenario, the impact of the frequency of metal formwork materials usage on environmental performance could not be accurately evaluated. The assessment was based on individual materials, and the formwork systems were assumed to have been constructed 500 times for comparison purposes only.

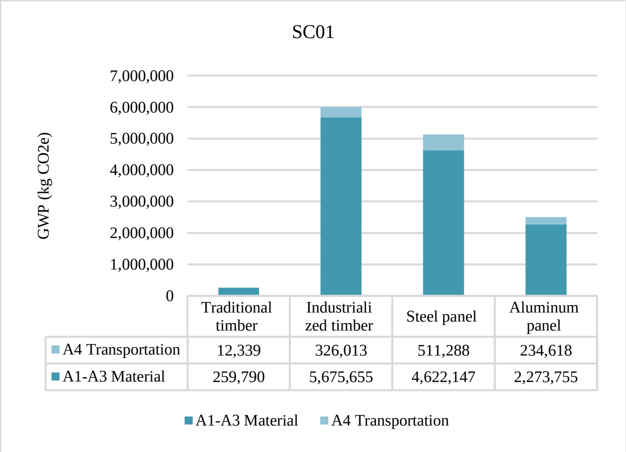

Figure 8. Global warming potential of formwork materials in A1-A3 and A4 stages according to *SC₀₁*

The amount of surface material contained in the industrial timber formwork system (82,660 m²) is higher than that in the steel panel formwork system (75,300 m²), and even the amount of steel panels used in the load-bearing materials is almost twice that of the industrial beams. It can be interpreted that the increase in environmental impact values of industrial timber formwork material may be due to the effect of the phenolic resin used during the production of plywood from birch wood, which contains formaldehyde-based adhesives. In the A4 stage, when steel and industrial timber, obtained from the same distance, are compared, it is seen that steel causes more emissions since it requires more truck supply due to the increase in weight. On the other hand, the traditional timber formwork system has the lowest carbon emission compared to other systems since it is produced from raw wood that has not undergone any industrial processing and is supplied from the nearest region.

When the environmental impact values for SC_{01} are examined within the system boundaries, it is observed that industrial timber is in first place and steel panel is in second place in general (Figure 9, Table 6). The reason for this is that processed wood is used intensively in the industrial timber formwork system although it has a similar amount to traditional timber formwork. In terms of ODP, the steel panel formwork system stands out. As a result of the reaction of chlorofluorocarbons, such as mercury (Hg), polychlorinated biphenyl (PCB), and sulfur dioxide (SO_2) that are byproducts of steel production, with ozone gas, erosion occurs in the ozone layer. This causes the ODP value of steel to increase.

As a result of the environmental assessment of SC_{02}, which considered the service lives of the formwork materials, it was observed that the industrial timber formwork system had the greatest impact, as in SC_{01}. It was also found that the traditional timber formwork ranked second in the environmental impact ranking, mainly due to its eight-fold increase in material usage compared to the industrial timber formwork. On the other hand, the steel panel system was found to have the lowest impact rate due to a significant decrease in the wear-out coefficient of the system (as shown in Figure 10).

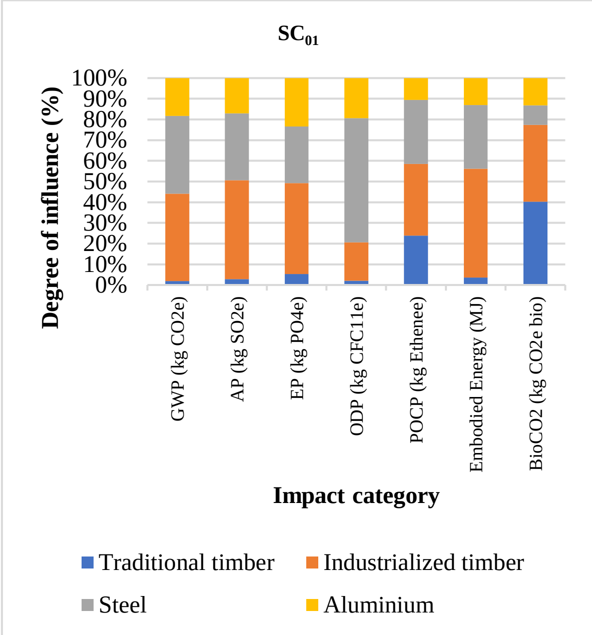

Figure 9. Global warming potential of formwork materials in A1-A3 and A4 stages according to *SC₀₁*

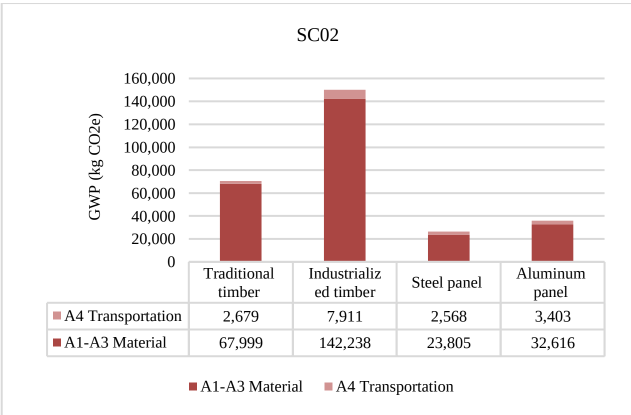

Figure 10. Comparison of global warming potential in stages A1-A3 and A4 according to *SC₀₂*

According to SC_{02}, the impact rate of traditional timber has increased in total values, unlike SC_{01}, even though there is a general decrease for all formwork systems due to the increased differences in the wear-out coefficients (as shown in Table 6). The traditional timber formwork system has the highest impact value, especially in the EP and POCP classes, due to the high use of natural wood. The reason for the increase in EP values is the excessive use of wood in traditional timber formwork systems, which leads to an increase in by-products such as wood chips and sawdust. These by-products, when mixed with water through surface flows, can cause an increase in the number of algae living in aquatic habitats, leading to eutrophication that harms other living organisms and reduces water quality [39]. Photochemical ozone arises due to the oscillations occurring in the industrial and transportation stages, which manifest themselves in the form of fog in the lower layers of the atmosphere in the presence of sunlight. The main causes of this formation are volatile organic compounds (VOCs) and nitrogen oxide (NO_x). The increase in this impact value can be explained by the increased amount of wood produced, which causes more emissions in terms of transportation and

VOCs release. Additionally, an increase is observed in the biogenic carbon storage ($bioCO_2$) potential as a result of the increasing amount of wood used (as shown in Figure 11 and Table 6).

Lo [22] emphasized that excessive use of wood would cause deforestation. Therefore, it is essential to consider plastic formwork systems as an alternative, which can be reused and have low production costs. In this study, it was found that metal formwork systems could achieve a gain of 70% in the initial investment cost and 60.6% in the global warming potential thanks to their multiple uses.

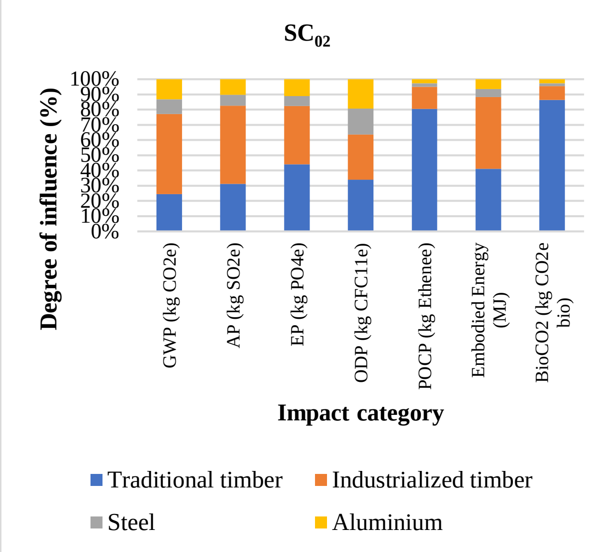

Figure 11. Environmental impact values of formwork systems according to *SC_{02}* (EN-15978)

Table 6. Environmental impact values of *SC_{01}* and *SC_{02}*

Formwork Type	GWP (kg CO_2e)	AP (kg SO_2e)	EP (kg PO_4e)	ODP (kg CFC_{11}e)	POCP (kg Ethenee)	Embodied Energy (MJ)	$BioCO_2$ (kg CO_2e bio)
SC_{01}							
Traditional timber	2.84E+05	2.25E+03	8.46E+02	1.78E-02	1.39E+03	1.25E+07	5.47E+06
Industrialized timber	6.33E+06	3.73E+04	6.91E+03	1.59E-01	2.02E+03	1.85E+08	5.03E+06
Steel panel	5.64E+06	2.52E+04	4.30E+03	5.16E-01	1.80E+03	1.08E+08	1.27E+06
Aluminum panel	2.74E+06	1.33E+04	3.67E+03	1.67E-01	6.10E+02	4.57E+07	1.79E+06
SC_{02}							
Formwork Type	GWP (kg CO_2e)	AP (kg SO_2e)	EP (kg PO_4e)	ODP (kg CFC_{11}e)	POCP (kg Ethenee)	Embodied Energy (MJ)	$BioCO_2$ (kg CO_2e bio)
Traditional timber	7.34E+04	5.70E+02	1.99E+02	4.34E-03	2.83E+02	4.11E+06	1.17E+06
Industrialized timber	1.58E+05	9.40E+02	1.72E+02	3.80E-03	5.09E+01	4.70E+06	1.22E+05
Steel panel	2.89E+04	1.31E+02	2.90E+01	2.18E-03	8.16E+00	5.07E+05	2.54E+04
Aluminum panel	3.94E+04	1.87E+02	4.99E+01	2.48E-03	9.31E+00	6.53E+05	3.58E+04

3.2. Cost Analysis

The analysis shows that for building a single house, the traditional wooden formwork system is the most cost-effective option (at 3,650€), followed by the industrialized timber, aluminum, and steel panel systems, respectively. However, when it comes to constructing 500 houses for a mass housing project, the steel panel formwork system appears to be the most optimal solution (at 125,550 €), followed by the industrialized timber formwork system (at 150,076 €), as shown in Figure 12. Li [8] emphasized that the cost of the formwork system can account for almost half of the total construction cost of a reinforced concrete structure constructed on-site. Therefore, the reusability of formwork systems is crucial in terms of cost-effectiveness.

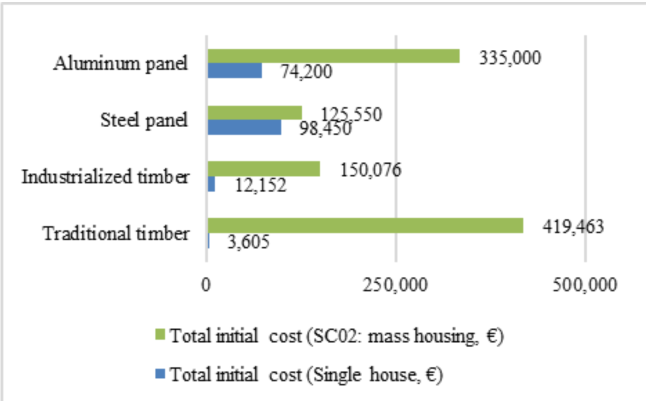

Figure 12. Total initial costs of formwork systems for a single house and mass housing

4. Conclusion

In this study, four different reinforced concrete formwork systems were examined to investigate the impact of service life on environmental impact and cost, under two scenarios: one-time use and multiple use cases based on service life. The results showed that multi-use metal formwork systems had better environmental performance than traditional timber formwork systems, achieving a 70% gain in initial investment cost and 60.6% reduction in global warming potential.

While timber is a natural material, excessive use can cause adverse environmental effects such as eutrophication and photochemical ozone formation. Therefore, it is essential to consider the quantity and quality of the selected materials. Although metals such as steel and aluminum may initially have negative environmental impacts, these effects can be minimized through multiple uses.

In terms of cost, traditional timber formwork systems were found to be more economical for single housing, while steel panel formwork systems were more economical for mass housing projects. Therefore, it is more rational to prefer steel panel systems in terms of both environmental impact values and cost for mass housing projects. Mahesh [19] argued that the costs of traditional timber formwork systems are not necessarily lower than steel formwork systems, and in some projects, they may even be higher. The results of this study confirm this argument.

The selection of a formwork system considering the service life of the selected material and the residential density of the project is of great importance in terms of reducing the environmental impact values caused by the materials and calculating the cost.

This study examined formwork systems in the context of economic and environmental sustainability, which are two of the three main criteria of sustainability. In future studies, different types of formwork systems can be evaluated with a holistic approach, considering environmental impact, cost, speed, workforce, quality, and waste production. The environmental effects of new-generation formwork systems obtained by digital printing can also be examined while considering cost and service life.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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