# Traditional formwork system sustainability performance: experts' opinion

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**Abstract.** The traditional formwork system is one of the commonly used systems in concrete construction. It is considered as one of the least observed activities in term of sustainability performance. In this paper, the sustainability performance of the traditional formwork has been assessed by using a multi-criteria assessment tool to facilitate the decision on the sustainability performance measurement. A quantitative five Likert scale survey study using judgemental sampling is employed in this study. A sample of 93 of engineering construction experts, with different fields including contractors, developers, and consultants in the Malaysian context has made the body of the collected primary data. The results show variety in the distribution of the respondents' working experience. The sustainability performance is considered moderately sustainable by the experts with only given 40.24 % of the overall total score for the three sustainable categories namely environmental, social and economic. Despite the finding that shows that the economic pillar was rated as the most sustainable aspect in comparison to the environmental and social pillars the traditional formwork system sustainability still needs enhancement. Further incorporation of the social and environmental pillars into the concrete construction the sustainability performance of traditional formwork system could be improved.

## 1. Introduction

Formworks are the moulds and dies that hold the concrete and carry the weight of materials, workers and equipment and for construction of reinforced concrete superstructure in building projects. [1, 2]. The conventional (Traditional) formwork system usually consists of standard plywood panels tied together with timber frame over their backs with horizontal members called walling to resisting the weight and horizontal force of wet concrete. A careful handling of the wall forms is needed as it is considered susceptible to edge and corner damage [3]. There is a need to choose a formwork type as there are different systems because they have their advantages and disadvantages. Cheap conventional formwork is too time consuming to use for larger structures. It has the tendency to damage and would seriously influence the cost, time, and quality of project delivery [4].

Conventional formwork can last longer if treated correctly. It is flexible and could be used in conjunction with engineered formwork for unique sections that require custom formwork [5]. However, conventional formwork also having disadvantages including requires extensive manpower, such as skill dependant and semi-skilled workers dependent would result in problems of cost, time, waste, poor finishes, leakages, and corrosion of structures. In term of cost and time, the formwork contributes approximately up to 20% of concrete cost and 60% of the concrete time [6]. The conventional timber formwork system is economical but highly environmentally undesirable [4].

Concerning the sustainability in formwork concrete construction, it is encouraged to follow most, if not all, sustainable construction criteria. They must be managed and assessed using multi-criteria means to facilitate the decision on the sustainability performance measurement [7]. Sustainable development is "the Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [8]. Sustainability includes social, economic and environmental pillars (Figure1.1).

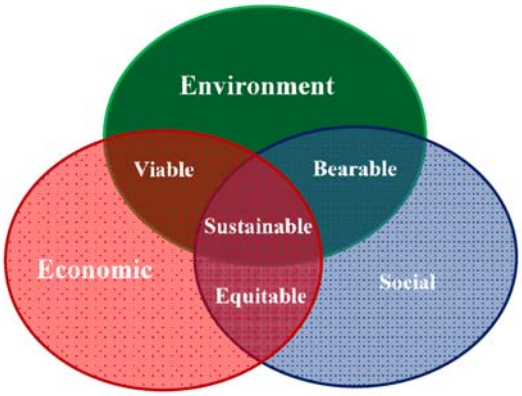


**Figure 1.** Sustainability three main pillars [9].

The construction should have a holistic design to meet the green building specifications to include materials used, energy consumption, air quality and adequate space [10]. However, in the current practice, the interest on the temporary work system is more due to its cost effectiveness ignoring other sustainability's factors [11]. This ignorance may happen due to several factors such as the focus on direct cost effectiveness and the level of awareness of the influence of the formwork type on the overall sustainability performance of the construction project [2]. The formwork system, in general, shows the least discussed aspect of concrete construction in civil engineering. Therefore, in this paper, we will present the result of the experts' opinion on sustainability requirement of the traditional formwork system using predeveloped multi-criteria indicators. The view of the experts could enlighten this area of research and provide the solution when knowing their views on the how far the existing traditional formwork system is fulfilling the sustainability requirement.

## 2. Methodology

Quantitative study design using five Likert survey designs has been used with the indicators as 1 = Strongly not responsive; 2 = less responsive; 3 = moderately responsive; 4 = responsive and 5 = strongly responsive in the study design. Online Google form has been used in a format of choice, and the questionnaire has been reviewed by the experts to check its face validity before the distribution. The survey consisted of two main sections, A for demographics data and B for sustainability rating. The results have been recruited and cleaned then analysed using the SPSS software version 23 (IBM, US).

### *2.1 Element pooling and rating*

Collection for the indicators has been used to evaluate the formwork system sustainability performance. The indicators have been grouped under the environment, social and economic pillars. The sustainability assessment model represents the relation between the indicators and the category using the factor loading as shown in Table 1. The sustainability score had been calculated using the mean and the factor loading as shown in equation (1) and (2).

$$\text{Indicator score} = \text{Mean} \times \text{Factor Loading} \quad (1)$$

$$\text{Category Score} = \sum \text{Indicator score} \quad (2)$$

The result of the model has been classified into four levels as 0-25% are basic, 26-50% moderate, 51-75% advanced and 76-100% optimum. The experts were asked to rate the fulfillment of the traditional formwork to the sustainability for each indicator.

**Table 1.** Formwork sustainability indicators.

| | Element Code | Element | Factor loading |
|---|---|---|---|
| ECO | ECO 1-1 | Labor Cost | .567 |
| | ECO 1-2 | Formwork Serviceability | .377 |
| | ECO 2-1 | Live-Cycle Cost | .595 |
| | ECO 2-2 | Installation Cost | .363 |
| | ECO 3-1 | Simplicity of Technology Use | .743 |
| | ECO 4-1 | Cost in Use | .669 |
| | ECO 4-2 | Material & Equipment Cost | .347 |
| ENV | ENV 1-1 | Energy and Resource Consumption | .996 |
| | ENV 1-2 | Waste Generation | .726 |
| | ENV 2-1 | Formwork Reusable | .979 |
| | ENV 2-2 | Using Renewable Material | .450 |
| | ENV 3-1 | Impact on Local Environment | .940 |
| | ENV 3-2 | Waste Efficiency | .367 |
| SOC | SOC 1-1 | Fire Safety | .993 |
| | SOC 1-2 | Safety Design of Formwork | .820 |
| | SOC 2-1 | Safety Measures | .559 |

## 3. Results and discussion

A total of 93 responses are collected with a variety of experience background from different types of companies as shown in Table 2 and Figure 2.

**Table 2.** Respondents' working experience and field of expertise.

| | Frequency | % |
|---|---|---|
| **Working Experience** | | |
| Less than 5 yrs | 22 | 23.7 |
| 5 – 10 yrs | 31 | 33.3 |
| 10 – 15 yrs | 21 | 22.6 |
| more than 15 yrs | 19 | 20.4 |
| Total | 93 | 100.0 |
| Total | 93 | 100 |
| **Field of Expertise** | | |
| Design | 27 | 29.0 |
| Management | 25 | 26.9 |
| Construction | 28 | 30.1 |
| Others | 13 | 14.0 |
| Total | 93 | 100 |

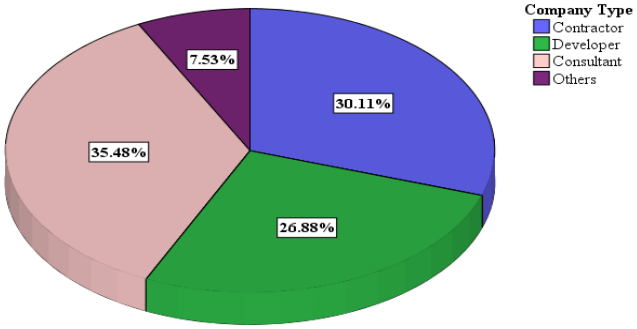


**Figure 2.** Respondents' company Type.

Regarding the respondent's knowledge on sustainable construction, 39.8 % of the respondents consider themselves as moderate experts in sustainable construction while 26.9 % of them just heard about it. Meanwhile; 23.7 % of the respondents are considered as experts in sustainability, and only 9.7 % had known nothing about sustainable construction (Figure 3). Despite the highest percentage of the respondents are moderately experts in sustainability, the results obtained from this survey are consistent as a total of 63.5 % of the respondents had enough knowledge to respond to the questionnaire.

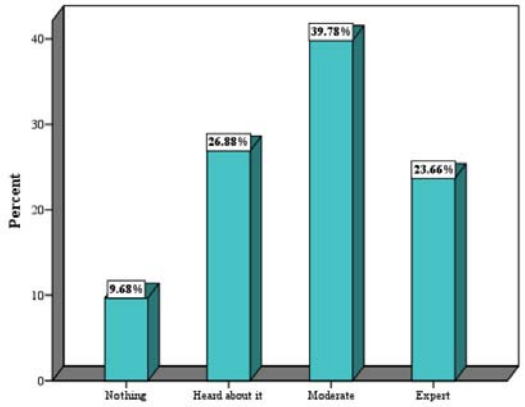


**Figure 3.** Respondents' knowledge level on sustainable construction.

As shown in Table 3 the element Eco 1-2 "Formwork Serviceability" had the highest mean average with 2.47 among the economic sustainability and followed closely by Eco 1-1 "Labour Cost" and Eco 4-1 "Cost in Use" with mean 2.45 and 2.42 respectively. As for the environmental category, the highest mean average is 2.18 for the element Env 1-1 "Energy and Resource Consumption" and following by to it both elements Env 2-1 "Formwork Reusable" and Env 3-2 "Waste Efficiency" with mean value 2.10. By looking at the social sustainability category, the highest mean average was for the element Soc 1-2 "Safety Design of Formwork" with mean 2.17. In general, these responses indicate that the respondent are not satisfied with the sustainability performance of the conventional formwork system as all assessment criteria achieve less than 2.5 in average. A quick glance on the survey responses the lowest performance was for installation cost, then to safety measures, which can be expected referring to the nature of the conventional formwork activities and work environment.

**Table 3.** Respondents' evaluation for the conventional formwork system fulfillment to the sustainability criteria.

| | Element Code | Element | Min | Max | Mean | Std. Dev |
|---|---|---|---|---|---|---|
| ECO | ECO 1-1 | Labor Cost | 2 | 4 | 2.45 | .648 |
| | ECO 1-2 | Formwork Serviceability | 1 | 4 | 2.47 | 1.077 |
| | ECO 2-1 | Live-Cycle Cost | 1 | 3 | 1.62 | .639 |
| | ECO 2-2 | Installation Cost | 1 | 3 | 1.52 | .649 |
| | ECO 3-1 | Simplicity of Technology Use | 1 | 4 | 2.12 | .980 |
| | ECO 4-1 | Cost in Use | 1 | 4 | 2.42 | .814 |
| | ECO 4-2 | Material & Equipment Cost | 1 | 4 | 1.99 | .916 |
| ENV | ENV 1-1 | Energy and Resource Consumption | 1 | 3 | 2.18 | .776 |
| | ENV 1-2 | Waste Generation | 1 | 3 | 1.97 | .583 |
| | ENV 2-1 | Formwork Reusable | 1 | 3 | 2.10 | .630 |
| | ENV 2-2 | Using Renewable Material | 1 | 3 | 1.67 | .738 |
| | ENV 3-1 | Impact on Local Environment | 1 | 3 | 1.89 | .700 |
| | ENV 3-2 | Waste Efficiency | 1 | 4 | 2.10 | 1.043 |
| SOC | SOC 1-1 | Fire Safety | 1 | 3 | 1.99 | .788 |
| | SOC 1-2 | Safety Design of Formwork | 1 | 3 | 2.17 | .556 |
| | SOC 2-1 | Safety Measures | 1 | 3 | 1.55 | .697 |

As the standard deviation for the responses were in the acceptable range "±2", the mean average was used to key in the values of the sustainability elements into the assessment model and calculate the final sustainability score of the conventional formwork system. The results are as shown in Figure 4, 5, 6, and

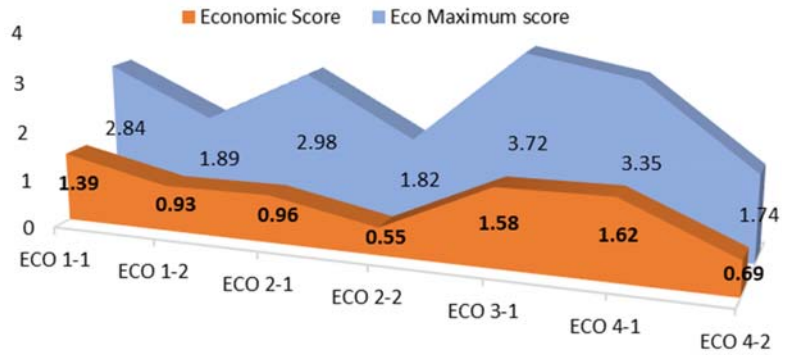


**Figure 4.** Economic Sustainability Score for conventional formwork.

The total sustainability score of the economic category was 7.7 from 18.3 total category scores i.e., 42.2%. The highest score in the economic categoy is for the element Eco 4-1 " Cost in Use" with value 1.62. While the lowest economic sustainability performance score was for the element Eco 4-2 "Material and Equipment Cost" with score only 0.69 (Figure 4).

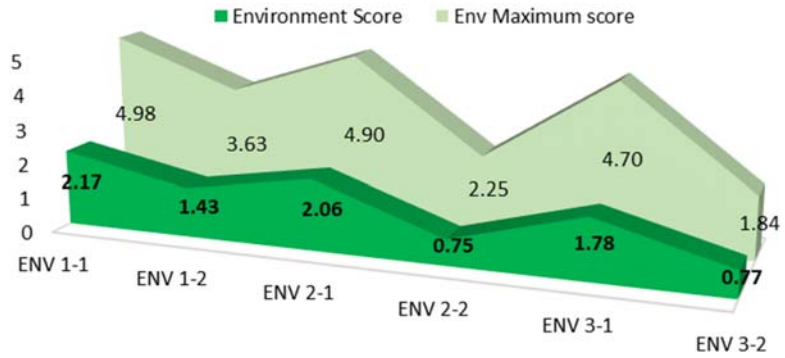


**Figure 5.** Environmental Sustainability Score for conventional formwork.

Referring to the environmental category (Figure 5), the total score is 8.96 of 22.3 i.e 40.2%. The highest score was for the element Env 1-1 "Energy and Resource Consumption" with 2.17, and the lowest score was for the elements Env 2-2 "Using Renewable Material" and Env 3-2 "Waste Efficiency" with the score 0.75 and 0.77 respectivly.

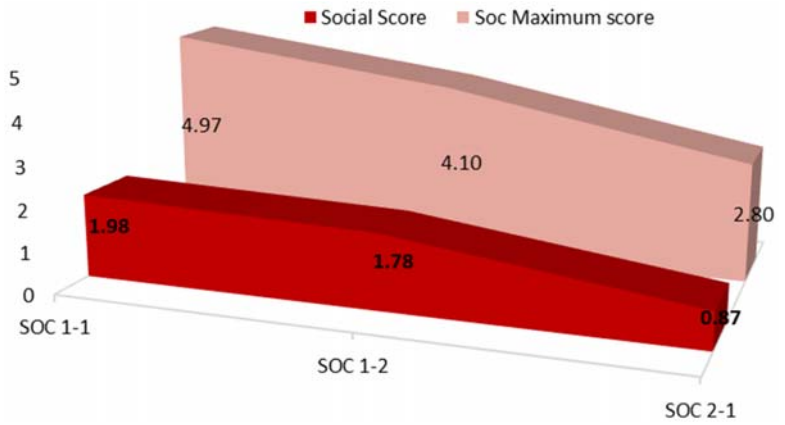


**Figure 6.** Social Sustainability Score for conventional formwork.

The social category had achieved total score 4.7 of 11.9 i.e., 38.9%, with the highest value for the elements Soc 1-1 "Fire Safety" and with score 1.98(Figure 6).

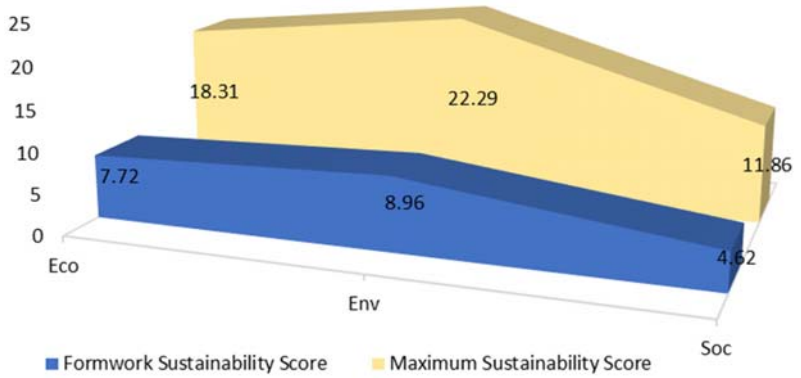


**Figure 7.** Sustainability Performance Score for conventional formwork.

The overall sustainability performance of the conventional formwork system is shown in Figure 7. The result is considered moderate for the three categories and also for the overall performance with the total score 40.6% as the results fall in the range of 26-50%.

## 4. Conclusion

As sustainability shows a trending growth for building development and safety, the sustainability measurement mode is not well developed and still in infancy stage. The findings of this study show that traditional formwork is performing well in term of the economy but not in social or environmental. This finding is tally with the reality in construction projects, as the use of conventional formwork system is mainly for its cost effectiveness. The sustainability pillars are not considered in the traditional formwork that calls for enhancement and focus in considering the environmental and social indicators to improve its sustainability performance.

## 5. References

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