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***Research paper***

# Barriers for developing building with low embodied energy multi criteria decision making approach

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**Abstract**

Design, construction management and procurement play a vital role in Building projects. Subsequent design decision, construction management activities and procurement policies tend to become barriers to sustainable construction by impacting negatively toward the environment. This paper pinpoints the barriers faced in embodied energy minimization by professionals in the Malaysia construction industry. Construction expert opinion was collected through design questionnaire survey which was scale according to saaty's with (1) equal importance to (9) extreme importance. The returned questionnaires were then inputted into the multi criteria decision making tools. Analytical network process (ANP) was used to determine which barrier among design, construction management and procurement has significant impact on the sustainability of building project. The barriers with most significant influence in the construction industry regarding embodied energy were found to be high level of wastage (CM01), Non-consideration of embodied impacts in assessment of offers (P01) and over specification in design due to additional factors of safety (D02).

***Keywords***: *Analytical Network Process; Barriers; Design; Embodied Energy; Management.*

## 1. Introduction

Environmental deterioration and shortage in energy globally have recently promted the research on embodied energy in international trade [1], [2]. The total energy summation needed to produce any goods or services is known as the Embodied energy. However, barriers encountered ranges from design, construction activities and management and procurement. The contribution of embodied energy in residential buildings is about 40% of the life cycle energy[3]. Building construction, operation and maintenance account for about 40 and 50% of all the energy usage and greenhouse gas emission globally [4], [5].Presently, sustainability idea is being incorporated into construction in several stages which include: design, construction management activities, procurement, operation and demolition. With the operational stage of the building require high energy consumption during the entire project life span [6], [7]. Through the right utilization of energy efficient strategies, the energy request can be minimized in 38% in new residential and commercial structures[8]. This study dwell into the barriers faced by professional in the Malaysian construction industry to achieve sustainability regarding embodied energy minimization. The barriers range from design, construction activities and management and procurement related issues. Stakeholders in the construction industry have varied opinion regarding the barriers and causes of embodied energy in buildings. Awareness issues into the sustainable construction practices related to embodied energy seems to be minimal within the construction industry expert.

Multi criteria decision in the form of Analytical network process developed by Thomas L. Saaty which is develop base on opinion of the expert for complex decision-making aid in various way of making appropriate decision within alternatives. ANP allows inter relationship among decision levels[9]. ANP generalizes the pairwise comparison process and it does not necessarily have a downward flow.

## 2. Methodology

The methodology adopted for this study is quantitative approach which is set to get insight or to understand a group[10].

### 2.1. Questionnaire survey for expert

A well design structured questionnaire serves as a tool in collecting primary information from the construction expert. The questionnaire was design base on saaty's scale of 1,3,5,7 and 9 representing, equal importance, moderate importance, strong or essential importance, very strong and extreme importance respectively. The expert includes Engineers and Architect that are registered with relevant professional bodies in Malaysia.

### 2.2. Analytical network process (ANP)

The Analytical Network Process which is a form of multi criteria decision making is used to input the results obtained from the questionnaire survey collected. ANP was used to make pairwise comparison of alternatives form the responses obtained regarding the barriers of embodied energy minimization and subsequently develop a model.

#### 2.2.1. Model development

The ANP model was develop by the jugdment of expert decision makers. The model which consist of three cluster and six nodes

consisting of network relationship was set. The relationship between each node within the respective cluster was generated toward other clusters and nodes.

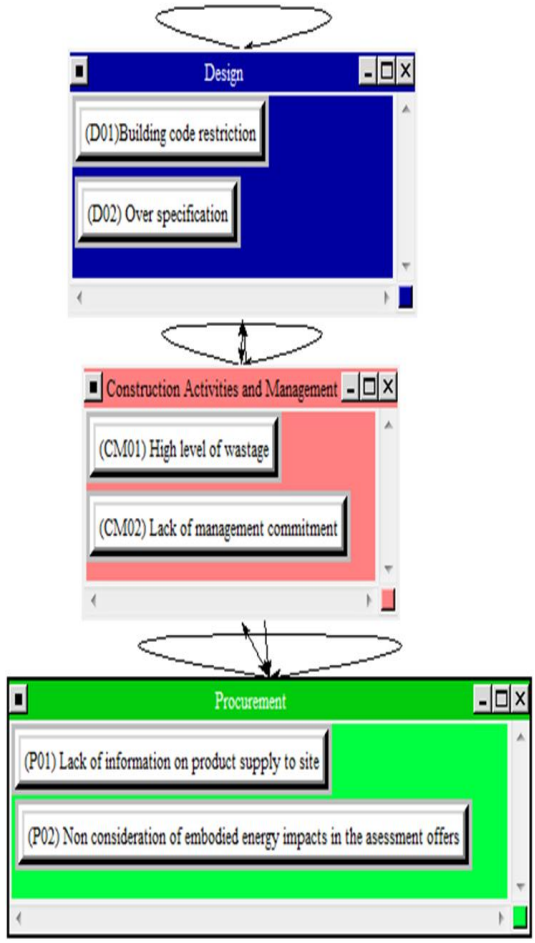


**Fig. 1:** Clusters and Nodes of the Model for Barriers of Embodied Energy Minimization.

### 2.2.2. Questionnaire

The expert opinion obtained from the questionnaire survey form was inputed with the assign weight given to each elements by the construction professionals. This was in accordance with saaty's scale of importance.

### 2.2.3. Establishment of pair wise comparation matrix

The pairwise comparasion was conducted after the incorporation of the expert judgement on level of importance of each of the element. The pairwise comparation was based on Saaty scale of importance.

### 2.2.4. Computation

The computation of the matrices involves obtaining the unweighted, weighted, and limit supermatrix. Also, the computation of priorities was also conducted to pinpoint the most significant barriers in relation to sustainable buildings with low embodied energy profile minimization.

## 3. Results and discussions

A total of Three (3) responses were obtained from the questionnaire distributed. According to Saaty, judgment provide by single expert or by a group whose opinion differs can be use in multi criteria decision[11].

### 3.1. The unweighted super matrix

The unweighted supermatrix are computed from the priorities obtained from the pairwise comparison. Each of the node column contains a priority of all the nodes that have been pairwise compared with respect to its and influence it respect to control criteria. It can be seen from table 1, 2 and 3 below, the unweighted supermatrix for respondent 1,2 and 3 respectively. The unweighted supermatrix shows the importance of nodes over others from various clusters. CM01 node from construction activities and management cluster under construction activities and management cluster is about seven (7) times importance than CM02 nodes in same cluster. The level of importance for procurement in table 1 is almost five (5) times.

**Table 1**: Respondent [1] Unweighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.875000 | 0.000000 | 0.833333 | 0.750000 | 0.833333 | 0.833333 |
| | CM02 | 0.125000 | 0.000000 | 0.166667 | 0.250000 | 0.166667 | 0.166667 |
| Design | D01 | 0.166667 | 0.833333 | 0.833333 | 0.833333 | 0.166667 | 0.166667 |
| | D02 | 0.833333 | 0.166667 | 0.166667 | 0.166667 | 0.833333 | 0.833333 |
| Procurement | P01 | 0.750000 | 0.833333 | 0.500000 | 0.166667 | 0.166667 | 0.166667 |
| | P02 | 0.250000 | 0.166667 | 0.500000 | 0.833333 | 0.833333 | 0.833333 |

**Table 2:** Respondent [2] Unweighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.833333 | 0.000000 | 0.750000 | 0.750000 | 0.833333 | 0.750000 |
| | CM02 | 0.166667 | 0.000000 | 0.250000 | 0.250000 | 0.166667 | 0.250000 |
| Design | D01 | 0.125000 | 0.750000 | 0.250000 | 0.125000 | 0.750000 | 0.125000 |
| | D02 | 0.875000 | 0.250000 | 0.750000 | 0.875000 | 0.250000 | 0.875000 |
| Procurement | P01 | 0.250000 | 0.250000 | 0.250000 | 0.125000 | 0.500000 | 0.500000 |
| | P02 | 0.750000 | 0.750000 | 0.750000 | 0.875000 | 0.500000 | 0.500000 |

**Table 3:** Respondent [3] Unweighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.833333 | 0.000000 | 0.750000 | 0.875000 | 0.833333 | 0.750000 |
| | CM02 | 0.166667 | 0.000000 | 0.250000 | 0.125000 | 0.166667 | 0.250000 |
| Design | D01 | 0.166667 | 0.250000 | 0.750000 | 0.125000 | 0.125000 | 0.166667 |
| | D02 | 0.833333 | 0.750000 | 0.250000 | 0.875000 | 0.875000 | 0.833333 |
| Procurement | P01 | 0.250000 | 0.250000 | 0.250000 | 0.166667 | 0.250000 | 0.500000 |
| | P02 | 0.750000 | 0.750000 | 0.750000 | 0.833333 | 0.750000 | 0.500000 |

### 3.2. The weighted super matrix

Table 4,5, and 6 below shows the weighted supermatrix which was obtained by multiplying each entry in a block of the component at the top of supermatrix by the priority of influence of the component. It was obtained using the multi criteria decision making process after the pairwise comparison of the selected alternative by the expert respondent. The element in the supermatrix is a column stochastic which means the sum of a column sums to one. Table 4,5 and 6 shows similar trend in which the weighted supermatrix behave and the columns vectors repeat it step which ultimately bring the iteration to an end. D02 in construction activities and management cluster have a higher importance range in table 1 compare to those in procurement.

**Table 4:** Respondent [1] Weighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.209918 | 0.000000 | 0.199922 | 0.179929 | 0.309448 | 0.309448 |
| | CM02 | 0.029988 | 0.000000 | 0.039984 | 0.059976 | 0.06189 | 0.06189 |
| Design | D01 | 0.116915 | 0.769082 | 0.584574 | 0.584574 | 0.055323 | 0.055323 |
| | D02 | 0.584574 | 0.153816 | 0.116915 | 0.116915 | 0.276617 | 0.276617 |
| Procurement | P01 | 0.043954 | 0.064252 | 0.029302 | 0.009767 | 0.049454 | 0.049454 |
| | P02 | 0.014651 | 0.01285 | 0.029302 | 0.048837 | 0.247269 | 0.247269 |

**Table 5:** Respondent [2] Weighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.215237 | 0.000000 | 0.137979 | 0.137979 | 0.189215 | 0.170293 |
| | CM02 | 0.043047 | 0.000000 | 0.045993 | 0.045993 | 0.037843 | 0.056764 |
| Design | D01 | 0.079623 | 0.644101 | 0.188278 | 0.094139 | 0.541540 | 0.090242 |
| | D02 | 0.557362 | 0.214700 | 0.564833 | 0.658972 | 0.180483 | 0.631692 |
| Procurement | P01 | 0.026182 | 0.035300 | 0.015729 | 0.007865 | 0.025504 | 0.025504 |
| | P02 | 0.078547 | 0.105899 | 0.047188 | 0.055053 | 0.025504 | 0.025504 |

**Table 6:** Respondent [3] Weighted Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.501474 | 0.000000 | 0.175808 | 0.20511 | 0.165282 | 0.148754 |
| | CM02 | 0.100295 | 0.000000 | 0.058603 | 0.029301 | 0.033056 | 0.049585 |
| Design | D01 | 0.053939 | 0.203171 | 0.514066 | 0.085678 | 0.090723 | 0.120963 |
| | D02 | 0.269697 | 0.609513 | 0.171355 | 0.599744 | 0.635058 | 0.604817 |
| Procurement | P01 | 0.018649 | 0.046829 | 0.020042 | 0.013361 | 0.018970 | 0.037941 |
| | P02 | 0.055946 | 0.140487 | 0.060126 | 0.066806 | 0.056911 | 0.037941 |

### 3.3. The Limit matrix

Table 7, 8 and 9 below shows the Limit matrix that was obtained from the weighted supermatrix to powers by multiplying it times itself. The limit matrix for each of the nodes in the respective cluster must sum to 1. Node D01 in design cluster has the highest importance rating in terms of limit matrix compare to other nodes in different clusters.

**Table 7:** Respondent 1 Limit Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.197476 | 0.197476 | 0.197476 | 0.197476 | 0.197476 | 0.197476 |
| | CM02 | 0.042483 | 0.042483 | 0.042483 | 0.042483 | 0.042483 | 0.042483 |
| Design | D01 | 0.458805 | 0.458805 | 0.458805 | 0.458805 | 0.458805 | 0.458805 |
| | D02 | 0.223283 | 0.223283 | 0.223283 | 0.223283 | 0.223283 | 0.223283 |
| Procurement | P01 | 0.030889 | 0.030889 | 0.030889 | 0.030889 | 0.030889 | 0.030889 |
| | P02 | 0.047063 | 0.047063 | 0.047063 | 0.047063 | 0.047063 | 0.047063 |

**Table 8:** Respondent [2] Limit Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.145742 | 0.145742 | 0.145742 | 0.145742 | 0.145742 | 0.145742 |
| | CM02 | 0.044043 | 0.044043 | 0.044043 | 0.044043 | 0.044043 | 0.044043 |
| Design | D01 | 0.135025 | 0.135025 | 0.135025 | 0.135025 | 0.135025 | 0.135025 |
| | D02 | 0.603584 | 0.603584 | 0.603584 | 0.603584 | 0.603584 | 0.603584 |
| Procurement | P01 | 0.014068 | 0.014068 | 0.014068 | 0.014068 | 0.014068 | 0.014068 |
| | P02 | 0.057539 | 0.057539 | 0.057539 | 0.057539 | 0.057539 | 0.057539 |

**Table 9:** Respondent [3] Limit Super Matrix

| Cluster | Nodes | Construction activities and management | | Design | | Procurement | |
|---|---|---|---|---|---|---|---|
| | | CM01 | CM02 | D01 | D02 | P01 | P02 |
| Construction activities and management | CM01 | 0.263736 | 0.263736 | 0.263736 | 0.263736 | 0.263736 | 0.263736 |
| | CM02 | 0.052278 | 0.052278 | 0.052278 | 0.052278 | 0.052278 | 0.052278 |
| Design | D01 | 0.150155 | 0.150155 | 0.150155 | 0.150155 | 0.150155 | 0.150155 |
| | D02 | 0.449891 | 0.449891 | 0.449891 | 0.449891 | 0.449891 | 0.449891 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Procurement | P01 | 0.019207 | 0.019207 | 0.019207 | 0.019207 | 0.019207 | 0.019207 |
| | P02 | 0.064732 | 0.064732 | 0.064732 | 0.064732 | 0.064732 | 0.064732 |

### 3.4. The priorities

Figure 2 shows the priority of nodes as selected by expert respondent 1. High level of wastage with a priority value of 0.82296 is the most significant barrier in embodied energy minimization which was followed by Buiding code restriction and Non-consideration of embodied energy impacts in the assessment of offers with a Normalized cluster value of 0.67265 and 0.60374 respectively.

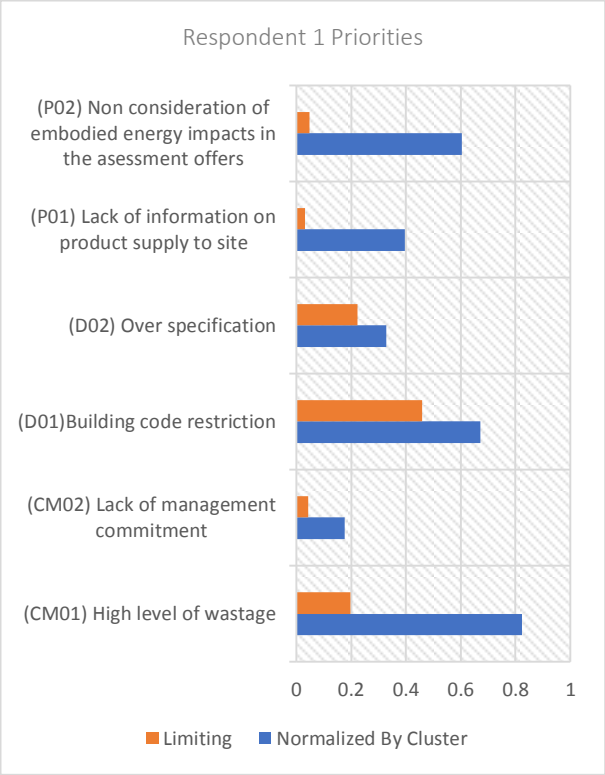


**Fig. 2:** Respondent One (R1) Expert Opinion Priority.

Respondent two (2) as depicted in figure 3 on the other indicate that the node in Design cluster which is overspecification (D02) is the most important barriers in embodied energy minimization which is then followed by the procurement cluster with Non consideration of embodied energy energy impact in the assessment of offers with each having a normalized cluster value of 0.81719 and 0.80354 respectively. High level of wastage also plays a vital role in environmental issues.

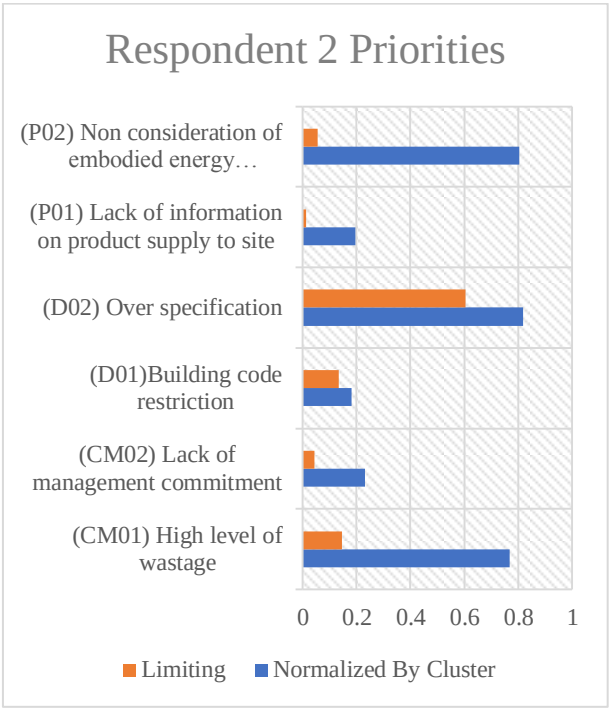


**Fig. 3:** Respondent Two (R2) Expert Opinion Priority.

The responses obtained from the third respondent (figure 3)indicates that High level of wastage, Non consideration of embodied energy impact at assessemnt of offers and overspecification as the most importance barrirs in minimizing embodied energy with the following normalized cluster values of 0.83457,0.77118 and 0.74976 respectively.

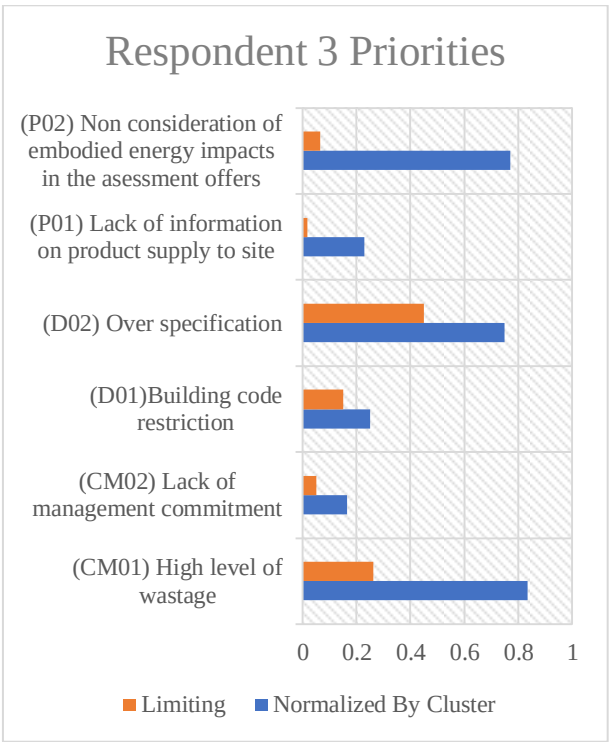


**Fig. 4:** Respondent Three (R3) Expert Opinion Priority.

## 4. Conclusion

Design, construction activities and management and procurement serve as the challenges faced in minimizing embodied by stake-

holders in the construction industry. Among these cluster, key element such as over specification, high level of wastage and non-consideration of embodied impact at the assessment of offer are the greatest problems faced and subsequently followed by restriction in the building code.

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