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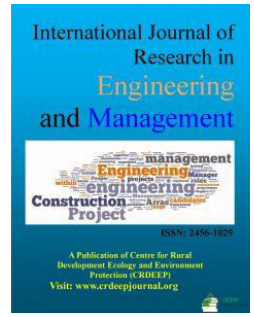

Full Length Research Paper

Application of Analytic Hierarchy Process in Evaluating Decision Alternatives: A Case Study

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ABSTRACT

Participants in the construction industry often face difficulties in making decisions to choose different design alternatives when alternatives are multi-criteria. This paper presents a model based on the Analytical Hierarchy Process (AHP) as a decision-making method for selecting multi-criteria design alternatives. Use The model is an application running on windows platform. It is developed using the C# language that uses the Access database to store tabular data that contains item data. In AHP algorithms, pair-wise comparison is used in two basic steps. First, the criteria are compared against each other. Second, compare alternatives versus each criterion in order to generate score for each alternative. The model provides multi-criteria decision-making solutions as (1) Choose the appropriate design alternative from a possible set of alternatives, (2) Classification of alternatives and prioritize preferences for alternatives in accordance with the criteria, (3) Evaluation of alternatives from best to worst and (4) Describe the impact of specific criteria on alternatives in terms of sensitivity analysis to verify the effect of multiple criteria on alternatives. This paper offers multiple alternatives in the case study for the application of the developed model. Which included Flat slab, Post tension and Hollow blocks for the design of a concrete ceiling of the project with multi-criteria. The results of the application of the model concluded that Hollow-Block is ranked as the first as a suitable alternative to the design of the project ceiling with score 35.1%, followed by the Post-tension is ranked in the second with score 34.1% and in the last rank the Flat slab with score 30.8 %.

Introduction

The AHP developed by Professor Thomas Saaty in 1980 allows for structuring the decision hierarchically (to reduce its complexity) and show relationships between objectives (or criteria) and the possible alternatives (Saaty, 1980). AHP is a basic approach to decision making. It is designed to cope with both the rational and the intuitive to select the best from a number of alternatives evaluated with respect to several criteria (Ranjbaran, 2013). In this process, the decision maker carries out simple pairwise comparison judgments which are then used to develop overall priorities for ranking the alternative. The AHP both allows for inconsistency in the judgments and provides a means to improve consistency. goal and subordinate features (decomposition), (2) pair-wise comparisons between elements at each level (evaluation), and (3) propagation of level-specific, local priorities to global priorities (synthesis) (Cheng, et al., 2002). Subordinate levels of a hierarchy, may include: objectives, scenarios, events, actions, outcomes, and alternatives. Alternative courses of action to be compared appear at the lowest level of the hierarchy. Pair-wise comparisons arc made between all elements at a particular level with respect to elements at the lowest level of the hierarchy (Saaty and Vargas, 2012).

Multi criteria analysis

In the decision-making context, this would imply some sort of standard by which one particular choice or course of action could be judged to be more desirable than another. Thus, the expression MCDA as an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter. Consideration of different choices or courses of action becomes a multiple criteria decision analysis (MCDA) problem when there exist a number of such standards which conflict to a substantial extent (Belton and Stewart, 2002). According to (Linkov and Moberg, 2012) this process can be described in six steps:

1. Define the problem: Identify the problem based on the
2. Problem Structuring: The problem is fleshed out by defining alternatives and criteria. Alternatives the potential management options are defined. The alternatives are what a decision maker is deciding among.
3. Define criteria: The alternatives and criteria are given numeric values. The alternatives are scored against the criteria.
4. Model Application: Input criteria weights and alternative scoring are used in an MCDA model to provide a decision about the best alternative according to the data given.
5. Planning, Extension and Verify solutions: Once the model has been run, the output can be used to make decisions or inform further planning.

Sensitivity analysis

Sensitivity analysis aims at examining how robust the ordering of alternatives, or the choice of a single alternative to relatively small changes in the components of MCDA (i.e., the problem structure, criterion values, criterion weights, and decision rules). Sensitivity analysis is most often performed on the criterion weights to test the robustness and veracity of a decision solution subject to changing the weights for a predetermined set of criteria across alternatives and revaluating the alternative ranks. This allows the effect of changes in criteria weights on the rank order of alternatives to be analyzed systematically (Ehrgott et al., 2010). Within the framework of the AHP, the comparison matrix is often inconsistent or large differences among the overall weights of the alternatives do not appear. Thus, it is very important to investigate how the components of a pairwise comparison matrix influence the consistency or weights. Sensitivity analysis is used to analyze the preferences expressed in the pair comparison judgements can be examined with the help of sensitivity analysis (Hullermeier et al., 2010; Gotzc et al., 2008).

The analytical hierarchy processes

AHP depends on methods of providing comparison relevant alternatives to specific criteria in the framework of decision structuring, defining the relative priorities of criteria in achieving the decision goal (marsh et al., 2017). Since components of the comparison matrix are obtained by pairwise comparisons between two elements, coherent consistency is not guaranteed. In the AHP Method, evaluation of alternatives is implemented by

conditions that must meet the needs of project stakeholders.

creating an accounting platform, designed to help stakeholders choose the best alternative to design (Omkarprasad, et al., 2006). This phase begins with the definition of criteria. Criteria are an essential component in the process of evaluating different design alternatives for judging alternatives. These criteria are based on the rationale of the design. Criteria weights are determined from the pairwise comparison matrix of the importance of the criteria relative to a 1-9 numerical ratio scale of comparisons (Saaty, 1980). Some criteria are not measurable therefore, the criteria weights are estimated according to the importance of criteria in the design process and utility functions for each.

AHP is composed of five main parts (Lucio,2013; Tam et al., 2007):

(1) Pair-wise comparison process;
(2) synthesizing the pair-wise comparison matrix;
(3) Determination of weights of alternatives and decision criteria;
(4) Calculating the priority for a criterion; and (5) Calculation of final comparison scores.

To get the score of alternatives, the pair-wise is compared to evaluate the relative importance of each criterion and compare alternatives with each other for each criterion to obtain the score of alternatives. In pair-wise comparison it is necessary to measure the consistency ratio (CR).

In AHP, the comparison is done in the form of pair of values and placed in matrix A is an n × n matrix where n denotes the number of criteria to be compared (KamalandAl-Harbi,2001). The pair-wise comparison matrices can also be represented as Eq 1.

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} a_{13} a_{1n} & & \\ 1/a_{12} & 1 & a_{23} a_{2n} & \\ 1/a_{13} & 1/a_{23} & 1 & a_{3n} \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & 1 \end{bmatrix} \ldots \text{Eq1}$$

Where i, j = 1… n, is established for evaluation of criteria and each criterion, aj is compared with another criterion, aj. Usually, these comparisons are quantified using a standard scale proposed by (Saaty, 1977) from 1 to 9. Where element i is equal to or more important than element j, and that the scale is the reciprocal of that scale (1/2, 1/3, …1/9) when element i is less important than element j and which has values ranging (Table1).

Table 1: Importance Scale (Saaty, 1977)

Intensity of Importance	Definition
1	Equal
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate values

Suppose we already know the relative weights of criteria: w1, w2…., wn. Assume that $\sum_{i=1}^{n} w = 1$ we can express them in a pairwise comparison matrix as Eq 2 and Eq 3:

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 & . & . & w_1/w_n \\ w_{21}/w_1 & w_2/w_2 & . & . & w_{21}/w_n \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ w_n/w_1 & w_n/w_2 & . & . & w_n/w_n \end{bmatrix} \text{..................Eq.2}$$

$$Aw=\begin{bmatrix} w_1/w_1 w_1/w_2 & . & w_1/w_n \\ w_{21}/w_1 w_2/w_2 & . & w_{21}/w_n \\ . & . & . \\ . & . & . \\ . & . & . \\ w_n/w_1 w_n/w_2 & . & w_n/w_n \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix} \text{........................ Eq.3}$$

Or in a matrix form:
$Aw = \lambda_{max} x w$
For every matrix of pairwise comparisons A, the consistency ratio must be calculated for the matrix, as defined in Eq. (4) and Consistency Index in Eq. (5) (Edwards and Barron, 1994).

$$C.R = \frac{C.I}{R.I} \text{ ....Eq.4}$$

$$C.I = \frac{\lambda_{max}-1}{n-1} \text{ ....Eq.5}$$

Where, Random Index (R.I.) is defined as the average C.I. for a large number of reciprocal matrices, λmax is the maximum eigenvalue of the matrix under consideration. Empirical studies conducted by Saaty have indicated that a deviation in consistency ratio of less than 10% is acceptable without adversely affecting the results. (Saaty, 1980; Hullermeier et al., 2010).

Case study

In this study the use of AHP is suggested in determining criteria weights and provides a way to rank the alternatives by deriving priorities. It helps stakeholders to make a multi-feature decision to select suitable design alternatives from multiple alternatives that have been created. The AHP allows evaluate of structure for hierarchical levels through the composition of a tree diagram. This method will contribute to facilitating the decision-making process in selecting appropriate design alternatives. For comparison purpose, developed workable alternatives are compared on the basis of suitable criteria. Specific weight is determined for each criterion according to its relative importance. Using the algorithm of pair-wise comparison, each criterion is compared with others. To evaluate the relative importance of each criteria, or the degree of prioritization that is used as a reference for comparison. The computing model will be developed using the AHP.

Criteria development

For decision-making in choosing suitable design alternatives, criteria must be established to evaluate and compare alternatives. The process is based on the relative weight of the criteria. The criteria have been defined for possible application to different types of buildings. An evaluation is implemented in the model, through the design of an organized mechanism, designed to help the user determine the suit alternative to the design. The criterion type is defined as average weights are determined of the criteria relative to a 1-9 numerical ratio scale of comparisons. While addition weights represent numerical and calculated criteria as cost and time scales (Fig.1).

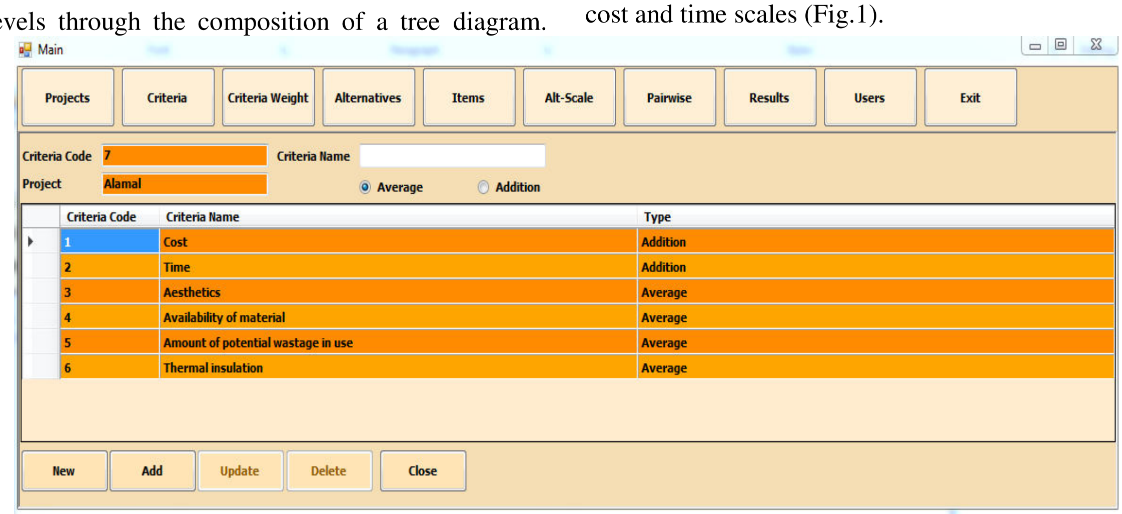


Fig 1: Model interface- define criteria

Alternative generation

The generation of alternatives involves analyzing a set of ideas that are determined according to the design criteria. There are a variety of possible alternatives that are measured by different criteria. The evaluation process was based on selecting a suitable design of the ceiling structure project. In this case three alternatives were created to design the ceiling structure as follows (Fig.2):

A. Flat slab.
B. Post-tension slab.
C. Hollow-block slab.

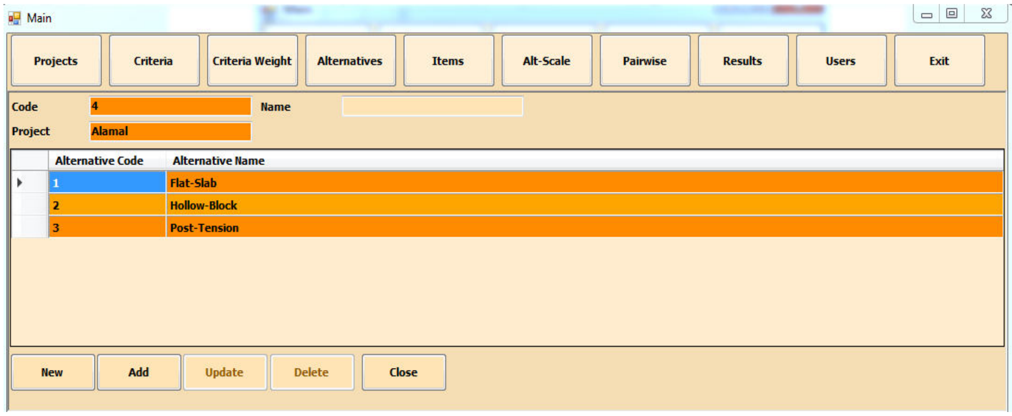


Fig 2: Model interface- define alternatives

AHP application

The project hierarchical structure was developed for alternatives and criteria to illustrate the problem of the situation (Fig.3). To get the score of alternatives, the pair-wise is compared to evaluate the relative importance of each criterion and compare alternatives with each other for each criterion to obtain the score of alternatives. The rank of the alternatives is set by comparing the criteria against each other.

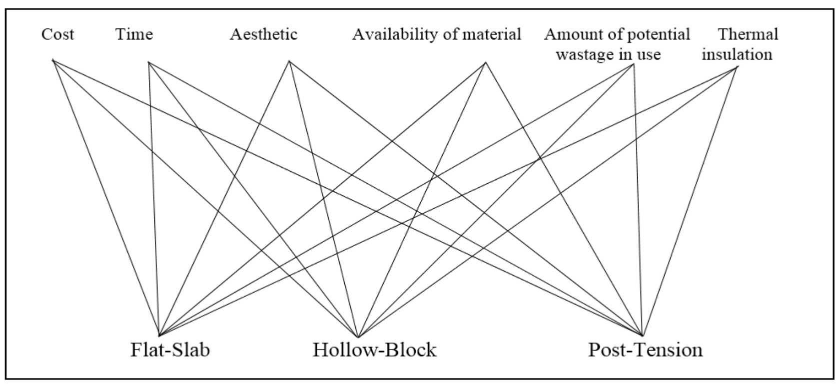


Fig 3: AHP diagram of the project

The model suggests setting importance of each criterion relative to the others. So, that this weight has associated numerical scale. Weight is determined to be greater than or less than or equal to, depending on the importance of each criterion. So that depends on the preferences, knowledge of the users and the rationale for the technical requirements of the type of building in fact (Fig.4).

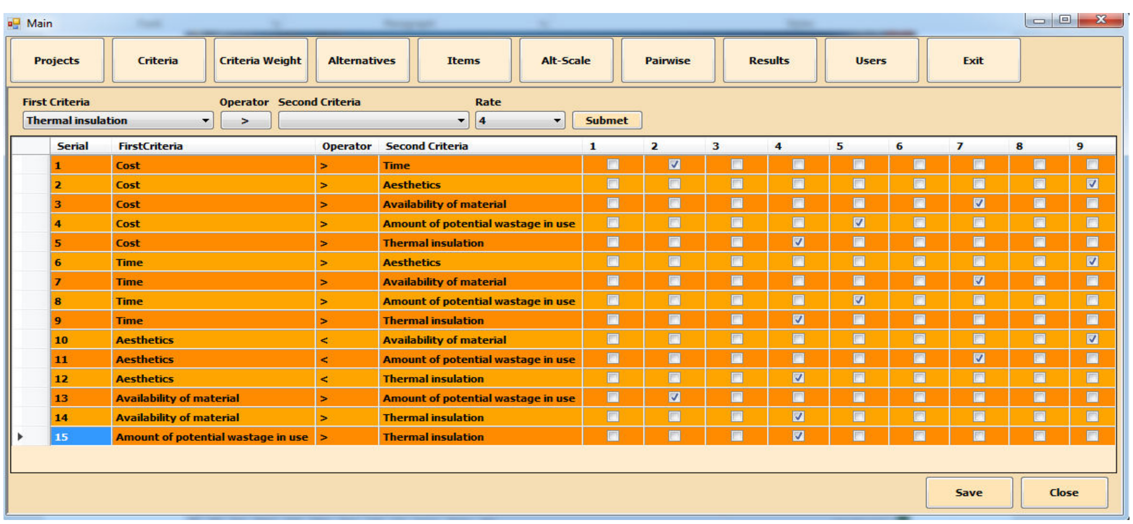


Fig 4: Criteria comparison

The scale corresponds to the relative importance awarded the criteria, according to the fundamental scale, when comparison is done in the form of pair of values and placed in a matrix where the criteria are compared with each other (Fig.5) and the alternatives are with the criteria (Fig.6). The rank of the alternatives is set and the comparison begins from the criteria levels to alternative levels using pairwise matrices. The scale used to construct matrices is the same for each of the criteria and alternatives 1-9 numerical ratio scale. The computational comparison procedure is applied automatically from the model as well as an evaluation of the consistency of these comparisons.

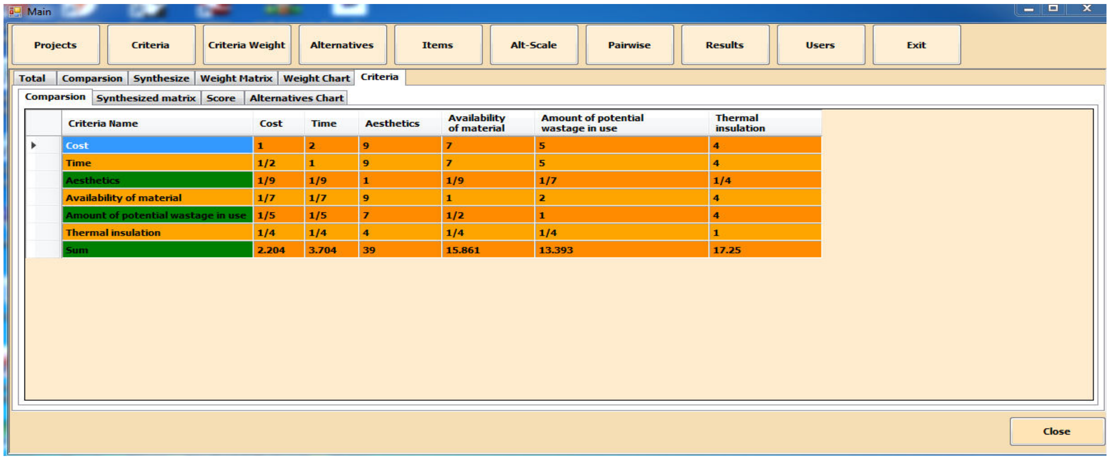


Fig 5: Pair-wise comparison forgiven criterion

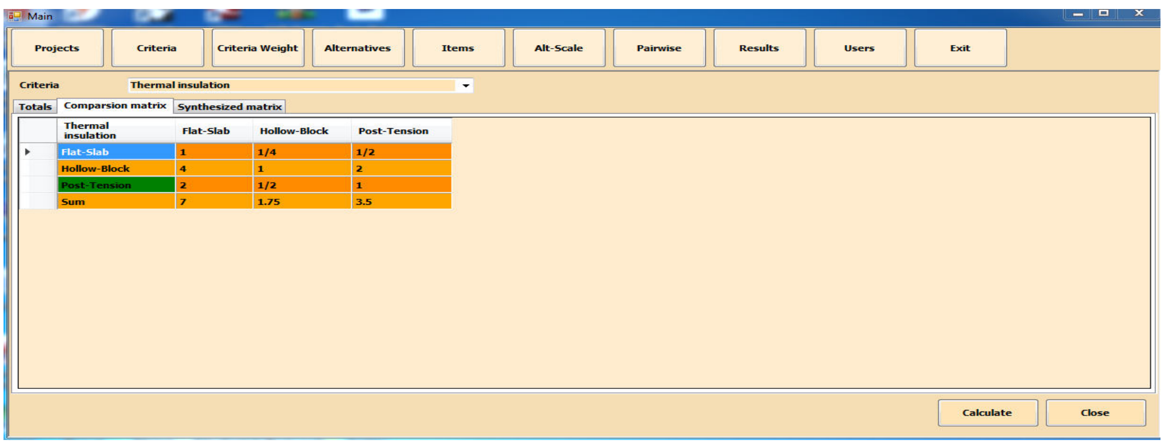


Fig 6: Pair-wise comparison of alternatives with respect to criteria

Then alternatives generated are evaluated in detail with respect to criteria assigned by the model (Fig7). The importance of criteria in the scale, is determined by the importance of criteria of the ratio scale and the average calculation of each criterion.

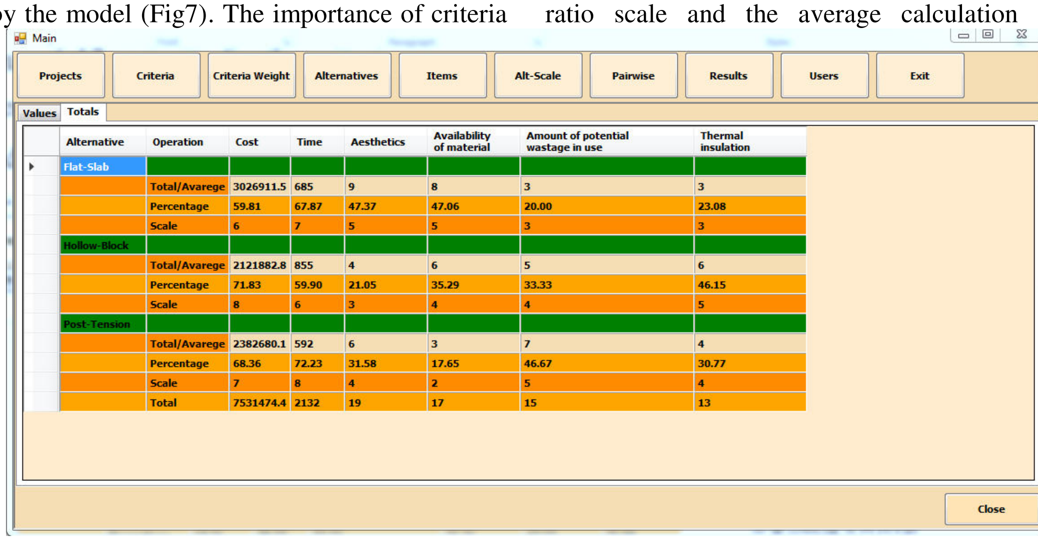
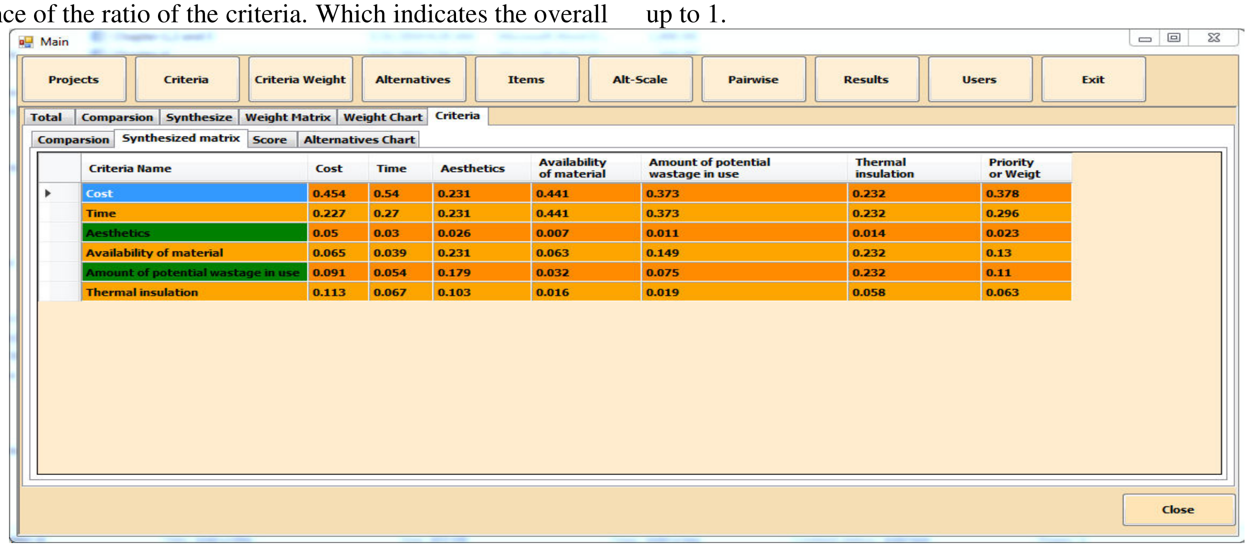


Fig 7: Alternatives evaluation

Analysis and results

After all the required criteria are added, the criteria weights will be calculated and the consistency ratio (CR) will be calculated automatically based on AHP algorithms. The model also refers to synthesizing the pair-wise for criteria according to the importance of each criterion, determining the priorities of the importance of the ratio of the criteria. Which indicates the overall preference for each alternative through the synthesized matrix. The pair-wise comparison of the criteria indicates that the priority or weight of the criterion of cost equals 37.8% in the first rank, then time 29.6%, availability of material 13.0%, amount of potential wastage in use 11.0 %, thermal insulation 6.3% and Aesthetic (Fig 8). Note that the value in the priority column sum up to 1.



Criteria Name	Cost	Time	Aesthetics	Availability of material	Amount of potential wastage in use	Thermal insulation	Priority or Weigt
Cost	0.454	0.54	0.231	0.441	0.373	0.232	0.378
Time	0.227	0.27	0.231	0.441	0.373	0.232	0.296
Aesthetics	0.05	0.03	0.026	0.007	0.011	0.014	0.023
Availability of material	0.065	0.039	0.231	0.063	0.149	0.232	0.13
Amount of potential wastage in use	0.091	0.054	0.179	0.032	0.075	0.232	0.11
Thermal insulation	0.113	0.067	0.103	0.016	0.019	0.058	0.063

Fig 8: Priority for the criteria

In the model, the sensitivity analysis aims at examining how robust the ordering of alternatives, or the choice of a single alternative to relatively small changes in the components of AHP (Fig 9). Sensitivity analysis is used to analyze the priorities expressed in the pair-wise comparison judgements. Sensitivity analysis is performed on the criterion weights to test the robustness and veracity of a decision solution subject to changing the weights for a predetermined set of criteria across alternatives and revaluating the alternative ranks. This allows the effect of changes in criteria weights on the rank order of alternatives to be analyzed systematically (Ehrgott et al., 2010).

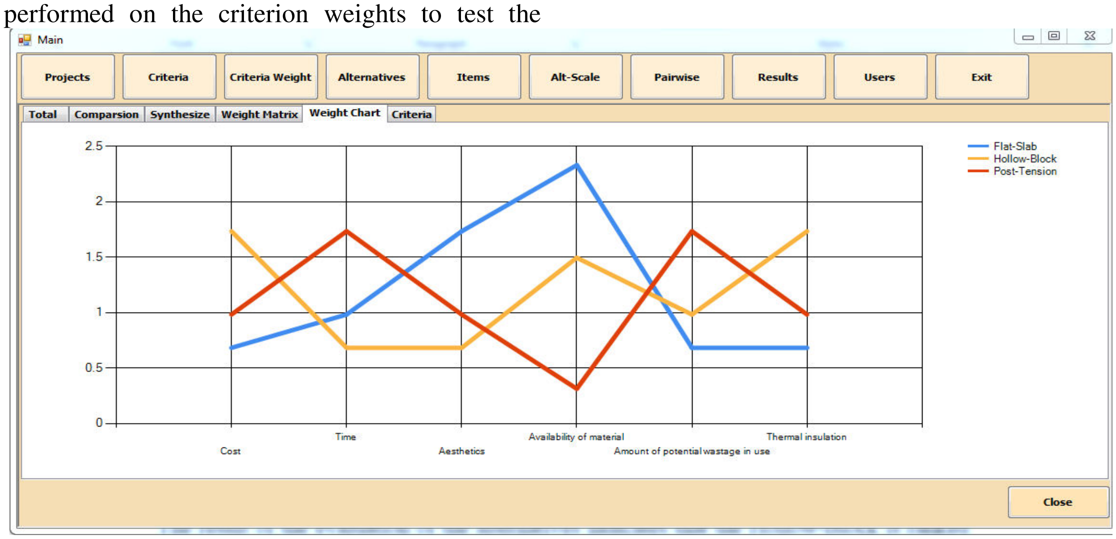


Fig 9: Effect of alternative weight

Calculate overall score of alternatives. The overall priorities are determined by means of a linear additive function, in which the relative priorities for an alternative are multiplied by the importance of the corresponding criteria and summed over all criteria. The AHP model shows which alternative has the highest priority (Fig10). The design of the ceiling of the Hollow-Block is suitable by comparing alternatives with multiple criteria (Fig11).

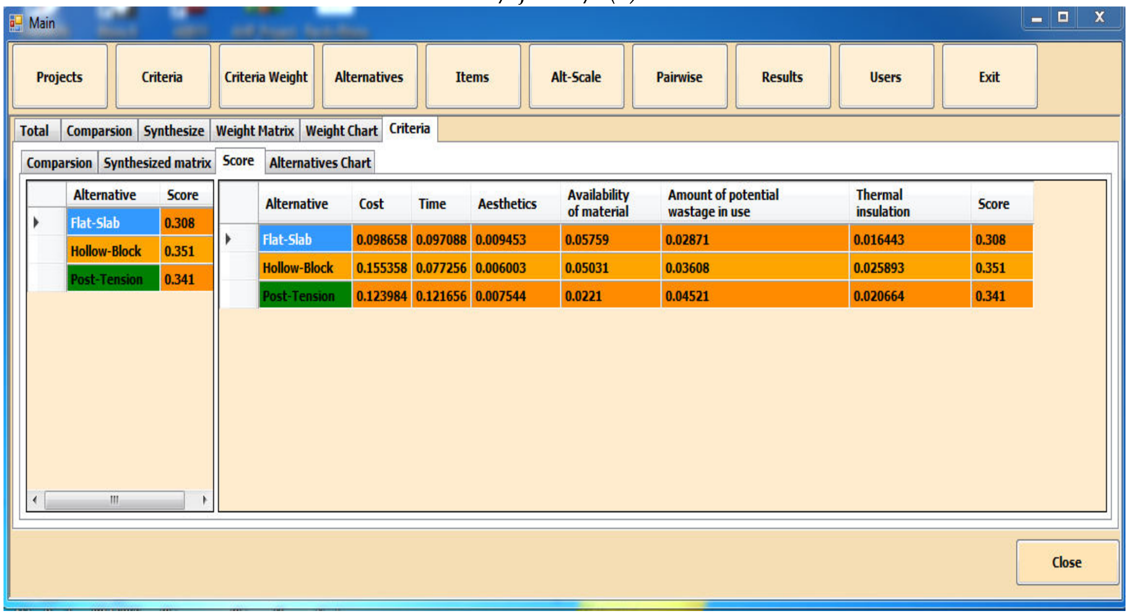


Fig 10: Alternatives score

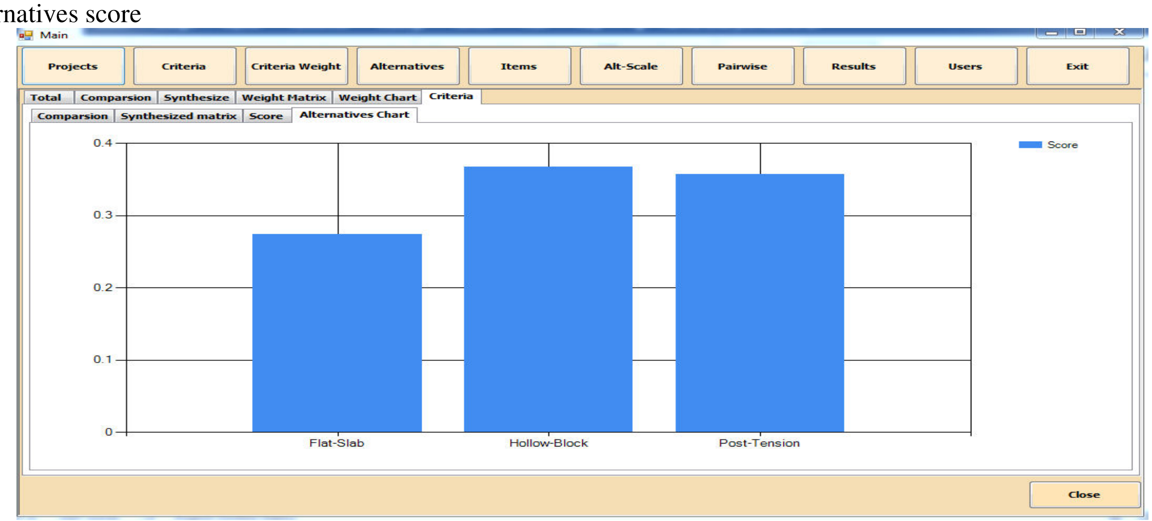


Fig 11: Alternatives ranking

Conclusion

The research presented in this paper was aimed at: developing a model to support decision-making in the selection of design alternatives. The process is done by extracting data to evaluate specific criteria and automate AHP algorithms. This model contributes to decision making, expand the user base, and helps to automatically classify alternatives in the model. Thus, prioritize and demonstrate the impact of multiple criteria on alternatives, thereby reducing uncertainty in decision-making and achieving better results for the selection of alternatives. A case study has been used to demonstrate the use of the developer model, validate its methods and algorithm. By contributing to decision-making, the contributes to decision making, expand the user base, and helps to automatically classify alternatives in the model. Thus, prioritize and demonstrate the impact of multiple criteria on alternatives, thereby reducing uncertainty in decision-making and achieving better results for the selection of alternatives. The result of the evaluation of the alternatives indicates that the Hollow-Block is ranked as the first as a suitable alternative to the design of the project ceiling with score 35.1%, followed by the Post-tension is ranked in the second with score 34.1% and in the last rank the Flat slab with score 30.8 %.

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