IDENTIFYING OPTIMAL CONCEPTUAL DESIGN OF A BRIQUETTING MACHINE

Abstract

Briquetting is a mechanical compaction process for increasing the density of bulky materials. Briquette is an example of biomass which is a renewable source of energy. As the world turn to renewable energy due to global warming, depletion of fossil fuel reserves and deforestation. The demand for briquetting machines is on the increase. This high demand and large market for briquetting machines has result in the need for briquetting machines with extended capabilities and design customization. This calls for an elaborate conceptual design phase. This research adopts a fuzzified Multi Criteria Decision Making (MCDM) model, (COPRAS) to identify the optimal conceptual design from four conceptual designs of briquette making machine, operating based on different principles. This was achieved by considering eight (8) design features and their sub features as the criterion to analyze, evaluate and measure the four conceptual designs. The result shows that in applying the COPRAS-F model, several decision makers choice can be factored into the process of choosing an optimal design, from a group of designs and still generate a valid result.

Keywords

Fuzzy COPRAS, Multicriteria Decision Making, Briquetting machine design, Triangular fuzzy number, Design concept selection

1.0 Introduction

The growing concerns about decreasing fossil fuel reserves along with the increasing concentration of atmospheric CO_2 are forcing humanity toward the search for new renewable sources of energy. It has been affirmed that biomass briquettes can be considered as an alternative energy source compared to wood fuel. The use of biomass briquette as a clean energy in households is a means to improve human health, lower climate change impacts and save hundreds of millions of people, especially for women and children from toiling during daily fuel collection (Ibrahim. *et al.*, 2020).However, as the world turns to biomass briquetting as a cheap source of energy, the demand for a sustainable briquetting machine has also increased. Therefore, manufacturers need to select the best design from alternative design concepts in order to meet up with the demand of customers and have a larger share of the competitive market that is flooded with multifarious designs (Olabanji and Mpofu, 2021a; Olabanji and Mpofu, 2020a).

The briquetting process involves increasing the density of a biomass material by mechanically compressing the material to form new high density regular shaped solid materials (Ajieh *et. al,* 2016). This new formed shaped material is called briquette. This process is used for forming fine particles into a desired shape. It can be regarded as a waste control measure in the case of production of briquettes from agricultural wastes such as corncob, rice husk (Ebunilo *et al.* 2016). Briquetting machines can be classified based on size of the briquettes, feeding of the material and mode of operation. Hence, the briquetting machines ranges from very simple manually operated briquetting machines to much more complex machines which are electrically powered and mechanically driven. Generally, briquetting machines are of two types; which are; the mechanical compression and screw pressing types (Inegbenebor 2002). The screw press type, uses a taper die that is heated externally while the briquettes are extruded continually from the exit point with the aid of a screw shaft. The essence of the heating is to reduce the friction between the walls of the die and the biomass material (Orhorhoro et. al, 2017). The mechanical compression types of briquetting machines are of two types; which are the hydraulic and piston compression. In the mechanical compression briquetting machines, the briquettes are obtained by punching (either hydraulically or with the aid of a piston) the biomass into a die by a reciprocating ram.

This level of high demand for briquettes has result in the need for briquetting machines with extended capabilities and design customization. This calls for an elaborate conceptual design phase of the briquetting machine. It therefore becomes important to evaluate different design concepts using a holistic approach for the comparison process in order to obtain an optimal design. To achieve this, a stake point of interest is identifying the optimal design from different conceptual design alternatives with design features and sub features using a Multi Criteria Decision Making (MCDM) model (Olabanji, 2024; Olabanji and Mpofu, 2021b). MCDM is employed in order to have a vigorous and unbiased evaluation process. Multi Criteria Decision Making (MCDM) models essentially considers the relative importance of each design feature and group the design sub features under their corresponding design features. This is necessary to provide a well-structured decision process. The selection of design criteria is generally based on the design requirements, product performance and decision of policy makers (Olabanji and Mpofu, 2014; Olabanji, 2020; Olabanji and Mpofu, 2020a).The MCDM theory is generally categorized into Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM) (Olabanji and Mpofu, 2019a; Olabanji and Mpofu, 2023). The MADM has been represented through the development of methodologies to enhance the ability to managed complicated optimization and decision-making aspects involving non-probabilistic uncertainty with the reason to understand, develop, and evaluate several alternatives in order to identify the optimal alternative as its finds its applicability in fields such as economic, engineering, management, and societal problems (Olabanji and Mpofu, 2019b; Olabanji and Mpofu, 2021).

Considering the multifarious nature of the design features and the diversity in units and dimensions of the parts of the design, it is usually difficult to assign crisp values to the design features, sub features and ratings of the alternative designs. In order to avoid bias in the decision process due to the diversity of the units and dimensions of the design features, the fuzzy membership function has been proven to be useful in the application of MCDM models because it helps avoids bias judgement due to its non-allocation of crisp value in the decision process (Gulcin and Fethullah, 2021; Hossam et. al, 2020; Tharmalingam *et. al*, 2023). The ranking and rating of the various design features and sub features is done using the Triangular Fuzzy Number (TFN) with Triangular fuzzy scale membership function or Trapezoidal Fuzzy Number (TrFN) (Olabanji and Mpofu 2020b). It is worthwhile to also note that other mathematical theories such as rough numbers have also been proving to be useful in the decision process. Aside from the fuzzy number theory, another mathematical theory that can be applied in the MCDM models is rough number (Olabanji, 2022).

Several MADM models have been developed and applied via fuzzy membership function in order to solve decision problems in the fields of engineering, science and management. Examples of these MADM models are Additive Ratio Assessment (ARAS), COmplex PRoportional ASsessment (COPRAS) (Chatterjee and Bose, 2013; Furtado and sola, 2020; Turanoglu *et. al*, 2016; Ghram *et. al*, 2022), Weighted Decision Matrix (WDM), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order Preference by similarity to Ideal Solution (TOPSIS), VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to mention a few. In some cases, some of these models are hybridized in order to improve the computational process and make the decision process more robust (Wu et. al, 2008;Arunodaya *et al*, 2020, Yand and Wang, 2020). Also, these models need to be investigated to ascertain their suitability for engineering and design concept selection. This is necessary because different design features are employed in the concept selection process. Also, since the design engineer is faced with the challenge of identifying the best design concept to choose for fabrication, there is a need to fill the gap in knowledge on which concept satisfy some percentage of the design features in order for the machine to gain recognition in the competitive market. To this end, the main contribution of this article is the application of COPRAS as a MADM model using triangular fuzzy membership function in order to obtain the optimal design concept of a briquetting machine considering four conceptual designs of the machine.

2.0 Methodology

In order to simplify the analysis, a framework for the application of the fuzzy COPRAS model to conceptual design selection is presented in Figure 1.0. The membership function developed for the linguistic terms considering the relevance of the sub-features and design features and the availability of the sub features and design features in the design concepts is presented in Figure 2. Also, the description of the design concepts is shown in Figure 3. Further, in this article, eight design features are established and applied in the decision process and each of the design features has several sub-features that can be used to describe the design features in order to have a robust decision process. A detail description of the design features and sub features alongside the design concepts is presented in Figure 3. At first, the relative importance of the sub features in the requirement of the design features in an optimal design are obtained in the form of linguistic terms using the established membership function considering three expert opinions. The weights of the sub features (W_{sf}) are obtained by determining the average weights of the TFNs and the summation of the weights of the sub features provided the weights of the design features (W_{df}) as presented in Tables 1 to 8 for the eight design features. Further, the availability of the sub features in the conceptual designs are obtained in the form of TFNs considering three expert's opinions. The matrices developed as a result of the availability of the sub features in the conceptual designs can be referred to as sub decision matrices as presented in Tables 9 to 16.

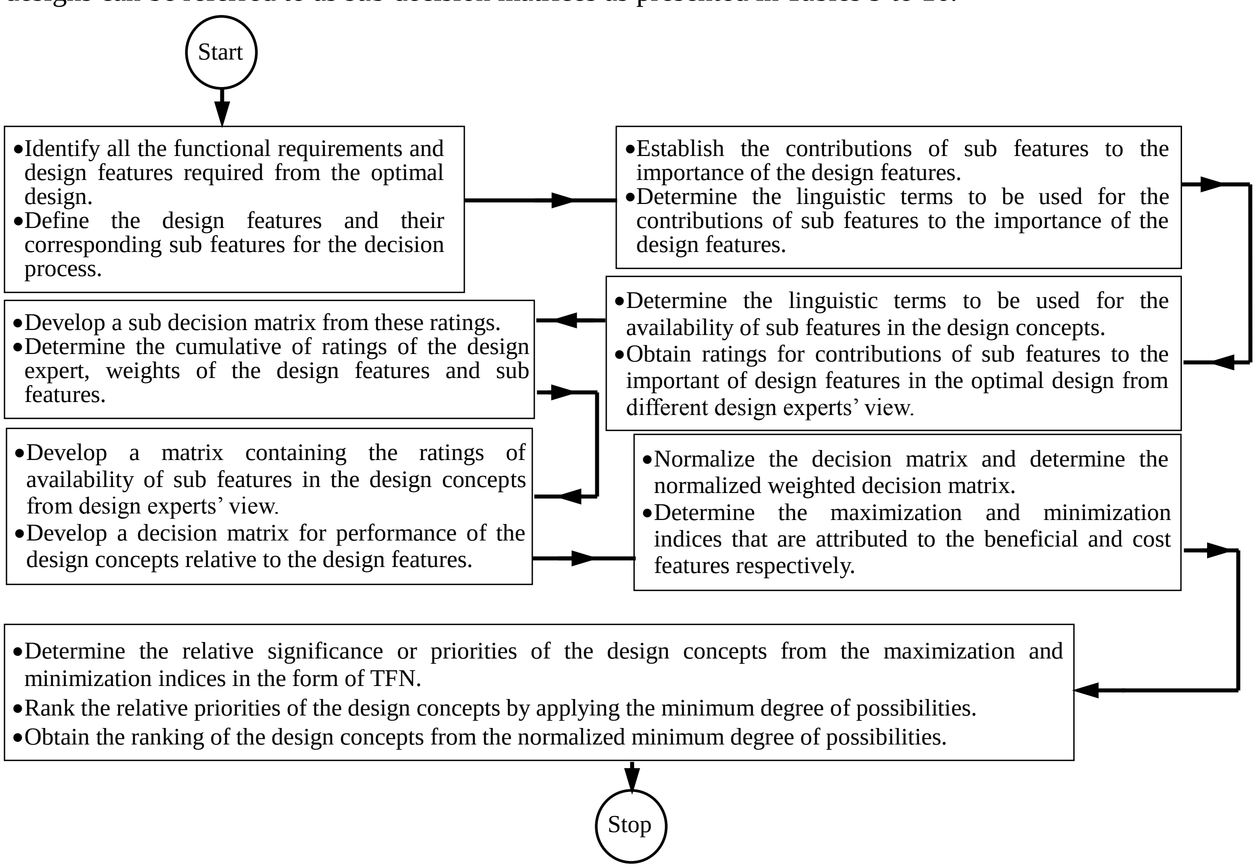
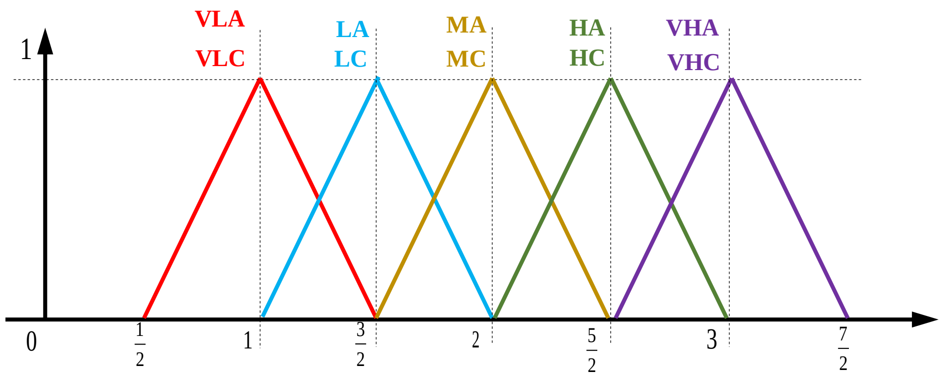


Figure 1. Framework for implementing fuzzy COPRAS in Design concepts evaluation(Olabanji and Mpofu, 2023)



VLC - Very Low Contribution; **LC** - Low Contribution; **MC** - Medium Contribution; **HC** - High Contribution; **VHC** - Very High Contribution; **VLA** - Very Low Availability; **LA** - Low Availability; **MA** - Medium Availability; **HA** - High Availability; **VHA** - Very High Availability

Figure 2. Fuzzy membership function and linguistic terms used in the decision process

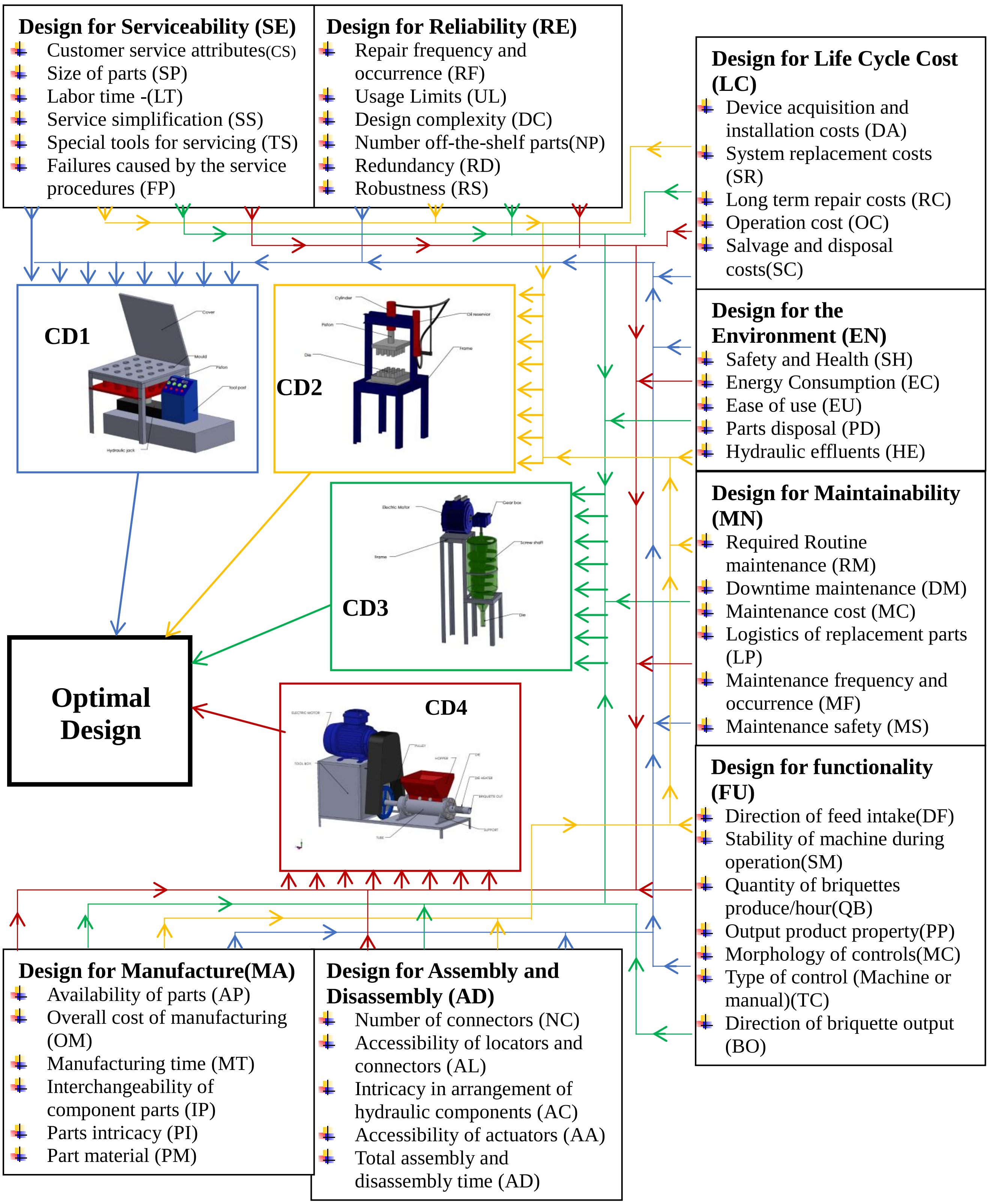

Design for Serviceability (SE)
Customer service attributes(CS)
Size of parts (SP)
Labor time -(LT)
Service simplification (SS)
Special tools for servicing (TS)
Failures caused by the service procedures (FP)
Design for Reliability (RE)
Repair frequency and occurrence (RF)
Usage Limits (UL)
Design complexity (DC)
Number off-the-shelf parts(NP)
Redundancy (RD)
Robustness (RS)
Design for Life Cycle Cost (LC)
Device acquisition and installation costs (DA)
System replacement costs (SR)
Long term repair costs (RC)
Operation cost (OC)
Salvage and disposal costs(SC)
Design for the Environment (EN)
Safety and Health (SH)
Energy Consumption (EC)
Ease of use (EU)
Parts disposal (PD)
Hydraulic effluents (HE)
Design for Maintainability (MN)
Required Routine maintenance (RM)
Downtime maintenance (DM)
Maintenance cost (MC)
Logistics of replacement parts (LP)
Maintenance frequency and occurrence (MF)
Maintenance safety (MS)
Design for functionality (FU)
Direction of feed intake(DF)
Stability of machine during operation(SM)
Quantity of briquettes produce/hour(QB)
Output product property(PP)
Morphology of controls(MC)
Type of control (Machine or manual)(TC)
Direction of briquette output (BO)
CD1
CD2
CD3
CD4
Optimal Design
Design for Manufacture(MA)
Availability of parts (AP)
Overall cost of manufacturing (OM)
Manufacturing time (MT)
Interchangeability of component parts (IP)
Parts intricacy (PI)
Part material (PM)
Design for Assembly and Disassembly (AD)
Number of connectors (NC)
Accessibility of locators and connectors (AL)
Intricacy in arrangement of hydraulic components (AC)
Accessibility of actuators (AA)
Total assembly and disassembly time (AD)

Figure 3. Framework for design features, sub features and design concepts

Table 1. Determination of weights for Functionality and its sub features

Experts Opinion	**DF**	**SM**	**QB**	**PP**	**MC**	**TC**	**BO**
DE1	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
DE2	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)
DE3	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)
Wsf	(1.0, 1.25, 1.50)	(0.75, 1.0, 1.25)	(0.58, 0.83, 1.08)	(0.58, 0.83, 1.08)	(0.75, 1.0, 1.25)	(0.67, 0.92, 1.17)	(1.08, 1.33, 1.58)
Wdf	(5.42, 7.17, 8.92)						

Table 2. Determination of weights for Serviceability and its sub features

Experts Opinion	**CS**	**SP**	**LT**	**SS**	**TS**	**FP**
DE1	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
DE2	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)
DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)
Wsf	(0.58, 0.63, 1.08)	(0.58, 0.83, 1.08)	(0.83, 1.08, 1.33)	(0.42, 0.67, 0.92)	(0.83, 1.08, 1.33)	(0.25, 0.5, 0.75)
Wdf	(3.50, 4.79, 6.50)					

Table 3. Determination of weights for Reliability and its sub features

Experts Opinion	**RF**	**UL**	**DC**	**NP**	**RD**	**RS**
DE1	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)
DE2	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
DE3	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)
Wsf	(0.67, 0.92, 1.17)	(0.75, 1.0, 1.25)	(0.67, 0.92, 1.17)	(0.67, 0.92, 1.17)	(0.83, 1.08, 1.33)	(1.08, 1.33, 1.58)
Wdf	(4.67, 6.17, 7.67)					

Table 4. Determination of weights for Life Cycle Cost and its sub features

Experts Opinion	**DA**	**SR**	**RC**	**OC**	**SC**
DE1	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
DE3	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
Wsf	(0.67, 0.92, 1.17)	(0.58, 0.83, 1.08)	(0.75, 1.0, 1.25)	(0.58, 0.83, 1.08)	(1, 1.25, 1.5)
Wdf	(3.58, 4.83, 6.08)				

Table 5. Determination of weights for Environment and its sub features

Experts Opinion	**SH**	**EC**	**EU**	**PD**	**HE**
DE1	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)
DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)
DE3	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)

Wsf	(0.83, 1.08, 1.33)	(1.08, 1.33, 1.58)	(0.92, 1.17, 1.42)	(0.42, 0.67, 0.92)	(0.75, 1.0, 1.25)
Wdf	(4.00, 5.25, 6.50)				

Table 6. Determination of weights for Maintainability and its sub features

Experts Opinion	**RM**	**DM**	**MC**	**LP**	**MF**	**MS**
DE1	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
DE2	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)
DE3	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)
Wsf	(0.75, 1.0, 1.25)	(0.58, 0.83, 1.08)	(1, 1.25, 1.5)	(1.08, 1.33, 1.58)	(0.58, 0.83, 1.08)	(0.75, 1.0, 1.25)
Wdf	(4.75, 6.25, 7.75)					

Table 7. Determination of weights for Manufacturing and its sub features

Experts Opinion	**AP**	**OM**	**MT**	**IP**	**PI**	**PM**
DE1	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
DE2	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)
DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
Wsf	(0.75, 1.0, 1.25)	(0.42, 0.67, 0.92)	(1.08, 1.33, 1.58)	(0.67, 0.92, 1.17)	(0.92, 1.17, 1.42)	(0.75, 1.0, 1.25)
Wdf	(4.58, 6.08, 7.58)					

Table 8. Determination of weights for Assembly and Disassembly and its sub features

Experts Opinion	**NC**	**AL**	**AC**	**AA**	**AD**
DE1	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
DE2	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
DE3	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
Wsf	(0.75, 1.0, 1.25)	(0.67, 0.92, 1.17)	(0.5, 0.75, 1)	(0.58, 0.83, 1.08)	(0.67, 0.92, 1.17)
Wdf	(3.17, 4.42, 5.67)				

Table 9. Availability of sub features of Functionality in the conceptual designs

Design concepts	Experts Opinion	DF	SM	QB	PP	MC	TC	BO
		(1.00, 1.25, 1.50)	(0.75, 1.00, 1.25)	(0.58, 0.83, 1.08)	(0.58, 0.83, 1.08)	(0.75, 1.00, 1.25)	(0.67, 0.92, 1.17)	(1.08, 1.33, 1.58)
CD1	DE1	(0.75, 1.00, 1.25)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)
	DE2	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)
	DE3	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	(3.74, 6.72, 10.57)							
CD2	DE1	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	DE2	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)
	DE3	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)
	(5.51, 9.13, 13.63)							
CD3	DE1	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)
	DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE3	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)
	(3.89, 6.97, 10.93)							
CD4	DE1	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.5, 0.75, 1)
	DE2	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)
	DE3	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	(4.28, 7.42, 11.44)							

Table 10. Availability of sub features of Serviceability in the conceptual designs

Design concepts	Experts Opinion	CS	SP	LT	SS	TS	FP
		(0.58, 0.83, 1.08)	(0.58, 0.83, 1.08)	(0.83, 1.08, 1.33)	(0.42, 0.67, 0.92)	(0.83, 1.08, 1.33)	(0.25, 0.5, 0.75)
CD1	DE1	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	DE2	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	DE3	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	(2.56, 4.70, 8.10)						
CD2	DE1	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE2	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	DE3	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)
	(2.85, 4.45, 8.43)						
CD3	DE1	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)
	DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)
	DE3	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	(2.65, 4.59, 8.23)						
CD4	DE1	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	DE2	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)
	DE3	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)

	(2.62, 4.58, 8.08)

Table 11. Availability of sub features of Reliability in the conceptual designs

Design concepts	Experts Opinion	RF	UL	DC	NP	RD	RS
		(0.67, 0.92, 1.17)	(0.75, 1.00, 1.25)	(0.67, 0.92, 1.17)	(0.67, 0.92, 1.17)	(0.83, 1.08, 1.33)	(1.08, 1.33, 1.58)
CD1	DE1	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)
	DE2	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.5, 0.75, 1)
	DE3	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)
	(3.86, 6.65, 10.19)						
CD2	DE1	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)
	DE2	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)
	DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	(4.58, 7.58, 11.33)						
CD3	DE1	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)
	DE2	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)
	DE3	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
	(4.40, 7.34, 11.03)						
CD4	DE1	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
	DE2	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	DE3	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)
	(3.31, 5.94, 9.31)						

Table 12. Availability of sub features of Life Cycle Cost in the conceptual designs

Design concepts	Experts Opinion	DA	SR	RC	OC	SC
		(0.67, 0.92, 1.17)	(0.58, 0.83, 1.08)	(0.75, 1.00, 1.25)	(0.58, 0.83, 1.08)	(1.00, 1.25, 1.50)
CD1	DE1	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)
	DE2	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)
	(2.67, 4.78, 7.51)					
CD2	DE1	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE2	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)
	DE3	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)
	(3.03, 5.31, 8.20)					
CD3	DE1	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)
	DE2	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	DE3	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)
	(2.82, 5.05, 7.90)					
CD4	DE1	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)
	DE3	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)

	(2.46, 4.54, 7.25)

Table 13. Availability of sub features of Design for Environment in the conceptual designs

Design concepts	Experts Opinion	**SH**	**EC**	**EU**	**PD**	**HE**
		(0.83, 1.08, 1.33)	(1.08, 1.33, 1.58)	(0.92, 1.17, 1.42)	(0.42, 0.67, 0.92)	(0.75, 1.00, 1.25)
CD1	DE1	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)
	DE2	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE3	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)
	(2.68, 5.03, 7.86)					
CD2	DE1	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)
	DE2	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	DE3	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	(2.26, 4.28, 6.92)					
CD3	DE1	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE2	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	DE3	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)
	(3.44, 5.82, 8.82)					
CD4	DE1	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)
	DE2	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.5, 0.75, 1)
	DE3	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1, 1.25, 1.5)
	(2.82, 5.03, 7.86)					

Table 14. Availability of sub features of Maintainability in the conceptual designs

Design concepts	Experts Opinion	**RM**	**DM**	**MC**	**LP**	**MF**	**MS**
		(0.75, 1.00, 1.25)	(0.58, 0.83, 1.08)	(1.0, 1.25, 1.50)	(1.08, 1.33, 1.58)	(0.58, 0.83, 1.08)	(0.75, 1.00, 1.25)
CD1	DE1	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)
	DE2	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	DE3	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)
	(3.69, 6.40, 9.86)						
CD2	DE1	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	DE2	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)
	DE3	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	(3.03, 5.55, 8.82)						
CD3	DE1	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	DE2	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)
	DE3	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	(3.69, 6.42, 9.90)						
CD4	DE1	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)

	DE2	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)
	DE3	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	(3.38, 6.04, 9.46)						

Table 15. Availability of sub features of Manufacturing in the conceptual designs

Design concepts	Experts Opinion	**AP**	**OM**	**MT**	**IP**	**PI**	**PM**
		(0.75, 1.00, 1.25)	(0.42, 0.67, 0.92)	(1.08, 1.33, 1.58)	(0.67, 0.92, 1.17)	(0.92, 1.17, 1.42)	(0.75, 1.00, 1.25)
CD1	DE1	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
	DE2	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1, 1.25, 1.5)
	DE3	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.5, 0.75, 1)
	(2.77, 5.19, 8.35)						
CD2	DE1	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)
	DE2	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(1, 1.25, 1.5)	(0.5, 0.75, 1)
	DE3	(0.5, 0.75, 1)	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)
	(3.16, 5.72, 9.03)						
CD3	DE1	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)
	DE2	(1, 1.25, 1.5)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)
	DE3	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	(3.92, 5.36, 8.55)						
CD4	DE1	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)
	DE2	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)
	DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	(3.36, 5.99, 9.36)						

Table 16. Availability of sub features of Assembly and Disassembly in the conceptual designs

Design concepts	Experts Opinion	**NC**	**AL**	**AC**	**AA**	**AD**
		(0.75, 1.00, 1.25)	(0.67, 0.92, 1.17)	(0.5, 0.75, 1)	(0.58, 0.83, 1.08)	(0.67, 0.92, 1.17)
CD1	DE1	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.75, 1.0, 1.25)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)
	DE2	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	DE3	(1.25, 1.5, 1.75)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(1, 1.25, 1.5)
	(2.03, 3.92, 6.49)					
CD2	DE1	(0.75, 1.0, 1.25)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(1, 1.25, 1.5)	(0.5, 0.75, 1)
	DE2	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)
	DE3	(1.25, 1.5, 1.75)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)
	(2.59, 4.69, 7.42)					
CD3	DE1	(0.75, 1.0, 1.25)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	DE2	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)
	DE3	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(1.25, 1.5, 1.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)
	(2.28, 4.28, 6.90)					
CD4	DE1	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(1.25, 1.5, 1.75)	(1, 1.25, 1.5)	(1.25, 1.5, 1.75)
	DE2	(0.25, 0.5, 0.75)	(0.75, 1.0, 1.25)	(1, 1.25, 1.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)

	DE3	(1.25, 1.5, 1.75)	(0.75, 1.0, 1.25)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(1, 1.25, 1.5)
	(2.54, 4.65, 7.38)					

The cumulative obtained from the availability of the sub features in the design concepts for each of the design features in Tables 9 to 16 are used to form the elements of the fuzzified decision matrix alongside the weights of the design features obtained from the aggregates obtained from Tables 1 to 8 as presented in Table 17. In order to ensure that the elements of the membership functions of the TFNs are contained in the range of [0, 1], the elements of the fuzzified decision matrix in Table 17 are normalized as shown in Table 18.

Table 17. Decision matrix showing the performance of conceptual designs in all the design features

Design features	Design Concepts			
	CD1	CD2	CD3	CD4
FU (5.42, 7.17, 8.92)	(3.74, 6.72, 10.57)	(5.51, 9.13, 13.63)	(3.89, 6.97, 10.93)	(4.28, 7.42, 11.44)
SE (3.50, 4.79, 6.50)	(2.56, 4.70, 8.10)	(2.85, 4.45, 8.43)	(2.65, 4.59, 8.23)	(2.62, 4.58, 8.08)
RE (4.67, 6.17, 7.67)	(3.86, 6.65, 10.19)	(4.58, 7.58, 11.33)	(4.40, 7.34, 11.03)	(3.31, 5.94, 9.31)
LC (3.58, 4.83, 6.08)	(2.67, 4.78, 7.51)	(3.03, 5.31, 8.20)	(2.82, 5.05, 7.90)	(2.46, 4.54, 7.25)
EN (4.00, 5.25, 6.50)	(2.68, 5.03, 7.86)	(2.26, 4.28, 6.92)	(3.44, 5.82, 8.82)	(2.82, 5.03, 7.86)
MN (4.75, 6.25, 7.75)	(3.69, 6.40, 9.86)	(3.03, 5.55, 8.82)	(3.69, 6.42, 9.90)	(3.38, 6.04, 9.46)
MA (4.58, 6.08, 7.58)	(2.77, 5.19, 8.35)	(3.16, 5.72, 9.03)	(3.92, 5.36, 8.55)	(3.36, 5.99, 9.36)
AD (3.17, 4.42, 5.67)	(2.03, 3.92, 6.49)	(2.59, 4.69, 7.42)	(2.28, 4.28, 6.90)	(2.54, 4.65, 7.38)

Table 18. Normalized Decision Matrix

Design features	Design Concepts			
	CD1	CD2	CD3	CD4
FU (0.39, 0.70, 1.00)	(0.15, 0.40, 0.74)	(0.30, 0.61, 1.00)	(0.16, 0.43, 0.77)	(0.19, 0.46, 0.81)
SE (0.06, 0.28, 0.58)	(0.05, 0.23, 0.52)	(0.07, 0.21, 0.55)	(0.05, 0.22, 0.53)	(0.05, 0.22, 0.52)
RE (0.26, 0.52, 0.78)	(0.16, 0.40, 0.70)	(0.22, 0.48, 0.80)	(0.20, 0.46, 0.78)	(0.11, 0.34, 0.63)
LC (0.07, 0.29, 0.51)	(0.06, 0.24, 0.47)	(0.09, 0.28, 0.53)	(0.07, 0.26, 0.51)	(0.04, 0.22, 0.45)
EN (0.14, 0.36, 0.58)	(0.06, 0.25, 0.49)	(0.02, 0.19, 0.42)	(0.12, 0.33, 0.59)	(0.07, 0.26, 0.50)
MN (0.28, 0.54, 0.80)	(0.14, 0.38, 0.68)	(0.09, 0.30, 0.59)	(0.14, 0.38, 0.68)	(0.12, 0.35, 0.64)
MA (0.25, 0.51, 0.77)	(0.06, 0.27, 0.55)	(0.10, 0.32, 0.60)	(0.08, 0.29, 0.56)	(0.11, 0.34, 0.63)
AD (0.00, 0.22, 0.43)	(0.00, 0.17, 0.38)	(0.05, 0.23, 0.46)	(0.02, 0.19, 0.42)	(0.04, 0.23, 0.46)

Further, the weights of the design features are considered and are applied to the elements of the normalized decision matrix. Agood characteristic, which is an advantage of the COPRAS method as a multiattribute decision model is the separation of the decision criteria into beneficial and cost criteria. This will assist in the decision-making process to know which criteria to minimize or maximize. This feature also plays a role in the decision process for identification of optimal design concept. It tells which of the design features will be cost or beneficial features. this will assist the design engineer to know how to optimize the design process. in the design process for the briquetting machine considered in this article, the beneficial features selected in this article are; functionality, serviceability, environment, assembly and disassembly while the cost features are reliability, life cycle cost, maintainability and manufacturing.Hence, the maximization (S_{max}) and minimization (S_{min}) indices that are associated to the beneficial and cost features respectively are determined as presented in Table 19. Also, the relative significance or priority of the design alternatives (Q_m) are obtained from the indices for maximization and minimization in the form of TFNs as shown in Table 19.

Table 19. Weighted normalized decision matrix and classification of design features

Design features		Design Concepts			
		CD1	CD2	CD3	CD4
Beneficial features	**FU**	(0.06, 0.28, 0.74)	(0.12, 0.43, 1.00)	(0.06, 0.30, 0.77)	(0.08, 0.32, 0.81)
	SE	(0.00, 0.07, 0.30)	(0.00, 0.06, 0.32)	(0.00, 0.06, 0.31)	(0.00, 0.06, 0.30)
	EN	(0.01, 0.09, 0.29)	(0.00, 0.07, 0.24)	(0.02, 0.12, 0.34)	(0.01, 0.09, 0.29)
	AD	(0.00, 0.04, 0.17)	(0.00, 0.05, 0.20)	(0.00, 0.04, 0.18)	(0.00, 0.05, 0.20)
	S_{max}	(0.068, 0.472, 1.493)	(0.124, 0.605, 1.767)	(0.084, 0.519, 0.599)	(0.089, 0.528, 1.605)
Cost features	**RE**	(0.04, 0.21, 0.55)	(0.06, 0.25, 0.63)	(0.05, 0.24, 0.61)	(0.03, 0.18, 0.49)
	LC	(0.00, 0.07, 0.24)	(0.01, 0.08, 0.27)	(0.00, 0.08, 0.26)	(0.00, 0.06, 0.23)
	MN	(0.04,0.20, 0.54)	(0.02, 0.16, 0.47)	(0.04, 0.20, 0.54)	(0.03, 0.19, 0.51)
	MA	(0.02, 0.14, 0.42)	(0.02, 0.16, 0.46)	(0.02, 0.15, 0.43)	(0.03, 0.17, 0.49)
	S_{min}	(0.101, 0.617, 1.747)	(0.112, 0.656, 1.828)	(0.117, 0.663, 1.836)	(0.092, 0.597, 1.715)
	$(S_{min})^{-1}$	(9.943, 1.621, 0.572)	((8.968, 1.525, 0.547)	(8.566, 1.509, 0.545)	(10.888, 1.675, 0.583)
	Q_m	(0.177, 0.121, 3.308)	(0.223, 1.215, 3.502)	(0.177, 1.123, 3.326)	(0.208, 1.199, 3.454)

3.0 Results and Discussion

In other to determine the optimal design concept from the priority values of the alternative design concepts the principle of minimum degree of possibilities is applied considering the TFNs of the priority values as expressed in equations 1 to 20. In essence, the defuzzified priority values for the design concepts can be obtained from equations 5, 10, 15 and 20 for conceptual designs one, two, three and four respectively as presented in equation 21.

For conceptual design one, we have;

$$V(Q_1 \geq Q_2, Q_3, Q_4) \quad (1)$$

$$V(Q_1 \geq Q_2) = \frac{0.223 - 3.308}{(0.121 - 3.308) - (1.215 - 0.223)} = 0.970 \quad (2)$$

$$V(Q_1 \geq Q_3) = 1 \text{ Since } (b_1 = b_3) \quad (3)$$

$$V(Q_1 \geq Q_4) = \frac{0.208 - 3.308}{(1.121 - 3.308) - (1.199 - 0.208)} = 0.975 \tag{4}$$

Hence, the Minimum $V(Q_1 \geq Q_2,\ Q_3,\ Q_4)$ = Minimum (0.970, 1, 0.975) = 0.970 (5)

For conceptual design two, we have

$$V(Q_2 \geq Q_1,\ Q_3,\ Q_4) \tag{6}$$

$$V(Q_2 \geq Q_1) = 1 \ \text{ Since } (b_2 > b_1) \tag{7}$$

$$V(Q_2 \geq Q_3) = 1 \ \text{ Since } (b_2 > b_3) \tag{8}$$

$$V(Q_2 \geq Q_4) = 1 \ \text{ Since } (b_2 > b_4) \tag{9}$$

Hence, the Minimum $V(Q_2 \geq Q_1,\ Q_3,\ Q_4)$ = Minimum (1, 1, 1) = 1 (10)

For conceptual design three, we have

$$V(Q_3 \geq Q_1,\ Q_2,\ Q_4) \tag{11}$$

$$V(Q_3 \geq Q_1) = 1 \ \text{ Since } (b_3 = b_1) \tag{12}$$

$$V(Q_3 \geq Q_2) = \frac{0.223 - 3.326}{\left(1.123 - 3.326\right) - \left(1.215 - 0.223\right)} = 0.971 \tag{13}$$

$$V(Q_3 \geq Q_4) = \frac{0.208 - 3.326}{(1.121 - 3.326) - (1.199 - 0.208)} = 0.976 \tag{14}$$

Hence, the Minimum $V(Q_3 \geq Q_1,\ Q_2,\ Q_4)$ = Minimum (1, 0.971, 0.976) = 0.971 (15)

For conceptual design four, we have

$$V(Q_4 \geq Q_1,\ Q_2,\ Q_3) \tag{16}$$

$$V(Q_4 \geq Q_1) = 1 \ \text{ Since } (b_4 > b_1) \tag{17}$$

$$V(Q_4 \geq Q_2) = \frac{0.223 - 3.454}{\left(1.199 - 3.454\right) - \left(1.215 - 0.223\right)} = 0.995 \tag{18}$$

$$V(Q_4 \geq Q_3) = 1 \ \text{ Since } (b_4 > b_3) \tag{19}$$

Hence, the Minimum $V(Q_4 \geq Q_1,\ Q_2,\ Q_3)$ = Minimum (1, 0.995, 1) = 0.995 (20)

Design Concepts Priority Values Ranking

$$\begin{bmatrix} Q_{\text{concept 1}} \\ Q_{\text{concept 2}} \\ Q_{\text{concept 3}} \\ Q_{\text{concept 4}} \end{bmatrix} = \begin{bmatrix} 0.970 \\ 1.000 \\ 0.971 \\ 0.995 \end{bmatrix} \Rightarrow \begin{bmatrix} 4 \\ 1 \\ 3 \\ 2 \end{bmatrix} \tag{21}$$

Considering equation 21, it can be stated that, design concept two is the optimal design concept of the briquetting machine considering the separation of the cost and beneficial features. Further, it can be observed that the priority value of design concept two is not too high compare to other design concepts. This is an indication that the Fuzzy COPRAS model used in this study did not just apportion values to the best design but carried out a comparative analysis of the availability of the sub-features in all the design concept thereby making it difficult to overscore a design concept. Also, the closeness of the priority values of the design concepts describes that other design concepts apart from two are also useful considering some design features which may be beneficial to the optimal design concept. Hence, there is tendency that other design concepts can be looked into to identify which of the design features can be improved in order to reduce the cost features and increase the beneficial features. It is also worthwhile to know that if the weights of the design features are changed due to their relative importance in the optimal design, the present result will not suffice and as such, it can be hypothetically stated here that the identification of design concept two as the optimal conceptual design is a function of the weight of the design features which may change subject to the consideration of the manufacturer and the desire of the intended user of the machine. The weight of the design features in this case can be attributed to the weights of the sub features and number of sub features in a particular design feature.However, the fact that a conceptual design is good considering the availability of a sub feature does not imply that it is the optimal design and as such there is a need to consider all other sub features and design features. As stated earlier, a distinctive characteristic of the computational process of the COPRAS model is the separation of the design features into cost and beneficial features. This separation contributed to the minimization and maximization values that plays a role inthe determination of the priority values for the design alternatives. The essence of the minimization and maximization values are to create a comparison platform where the strengths and weakness of the design concepts can be analyzed considering the cost and beneficial design features. Also, considering the availability of the sub features in the design concepts which serves as the sub decision matrix, it is evident that the decision of the experts is affected by the weights of the sub features and design features which have been obtained from other assessments made by other experts. This ensure that there is no bias in the decision process and as such there is certainty in the computational integrity of the fuzzy COPRAS model. The dependency of the optimal design on the weights of the design features and sub features can also be validated by comparing other MCDM models used for identification of conceptual design from a set of alternative designs. Although the designs under consideration may be different and likewise the design features adopted but the fact still remains that in MCDM models, a change in the weight of the design features will change the identified optimal conceptual design. In essence, the fuzzy COPRAS model can be applied to assessment of conceptual designs in order to identify the optimal design concept.This is possible,thanks to the ability of the model to aggregate the availability of the sub features in the design alternatives and the contributions of the sub features to the performance of the design features which can be classified as cost and beneficial features.

4.0 Conclusion

An important task in the conceptual design phase of a product that can not be overemphasized is the concept selection process. This article has been able to demonstrate how the fuzzy COPRAS model can be employed as a multiattribute decision making model to carry out the identification of optimal design of briquetting machine from a set of four (4) designs. The methodology considered eight design features by classifying them into beneficial and cost features. The results obtained from the application of the fuzzy COPRAS model showed that the model was able to identify a conceptual design of the briquetting machine. However, analyzing the results showed that the identification of the optimal design depends on the weights of the design features which is obtained from the aggregation of the relative relevance and contributions of the sub features towards the importance of the design features as needed in the optimal design. The methodology also showed that the cost and beneficial design features are instrumental in the determination of the minimization and maximization values of the design concepts respectively. These values contributed to the overall priority values of the design alternatives in the form of TFNs. The priority values are defuzzified using the minimum degree of possibility which compares all the priority values of the design alternatives. The implication of the result obtained from this article is that, an insight can be provided to the design engineer on the design features to improve in any of the design concepts thereby reducing cost features and improving the beneficial features of the design. However, future work is possible in the aspect of developing an application software for the COPRAS model that will help in reducing the calculation rigor and improving the computational integrity of the decision process. EHoweverfforts can also be made on integrating the model with other MCDM models in order to have a robust decision process.

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