Material selection for magnetic levitated GPS activated car using complex proportional assessment and additive ratio assessment approaches

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Abstract

Magnetic levitation is a technology that uses magnetism to lift vehicles on the basis of electromagnetism. It is the key substitute to fuels and other alternating fuels. The levitating force arises between the superconductor and the magnetic source used on the railway transport system or on the track provided under the road. In this research, it is proposed to design a prototype on the basis of development of high speed grand transportation system maglev car which will minimize the transport area, minimize time, no friction losses, no energy emission and zero pollution, thus bringing about environmental sustainability. It is also planned to design a GPS (Global Positioning System) and implementing sensors to detect barriers and to retard the motion of the car. Further improvement can be done to levitate the car without track for reducing the project cost and minimize the area. The main criterion of this paper is to select the best material for this maglev car. Therefore, complex proportional assessment (COPRAS) and additive ratio assessment (ARAS) approaches are used for selecting the best magnetic levitated car material in a given manufacturing arena. Ten different magnetic materials are selected based on their mechanical and physical properties and compared considering all the multi-conflicting material selection attributes. AA7075 is obtained to be the best material by ranking method and by comparing between these two methods.

Keywords: Magnetic levitation, COPRAS, ARAS, Global Positioning System

1. Introduction

Selection of proper material is the most elementary criteria in regards to manufacturing arena. In a proficient selection approach of materials, the best material is selected based on its potential to accomplish the manufacturing objectives with least cost. Inappropriate material selection indefatigably causes massive cost involvement and leads to immature product failure. So proper identification and selection of suitable materials with explicit functionalities in order to attain the desired product with least cost and intended applicability are necessary. For any particular application, the most important requirement may be the material strength, but several other factors are also necessary for optimal solution. Kaklauskas et. al. [1] used multiple criteria COPRAS method in contractor selection for the windows' replacement in the main buildings. Popovic et. al. [2] in 2012 considered the investment project selection based on their financial analysis criteria. The authors used crusty and hiatus values and analyzed the best project by using COPRAS and COPRAS-G methods. In 2011, Chatterjee et. al. [3] explored two novel MCDM methods, COPRAS and EVAMIX methods for selection of materials where ranking was used for best alternative materials, and proved that these two MCDM methods can be efficiently useful for solving real time material selection problems. Maity et. al. [4] used COPRAS-G method by considering nineteen different cutting tool materials and obtained their performances based on ten selection criteria. In 2013, Yazdani-Chamzini et. al. [5] used an integrated COPRAS-AHP methodology and selected the best project of renewable energy and validated with 5 tools of MCDM. A hybrid model was developed by Zolfani et. al. [6] using AHP and COPRAS-G methods for best material selection.

The essential opinion on material selection is thus focused on elimination and incorporation of the conflicting criteria [7,8]. In 2010, Turskis et. al. [9] implemented a new method ARAS-G method. The selection is based on delivery price, financial position, production specifications, standards and relevant certificates, commercial strength, and the performance of supplier, etc. In 2013, Turskis et. al. [10] further developed a model based on ARAS-G and AHP methods prioritizing of custom value. This paper gave an idea on the meaning and nature of urban cultural heritage, and the available methods for its valuation in the perspective of sustainable city growth. Bakshi et. al. [11] analyzed the configuration of the project selection problem using AHP and the ARAS method was used to acquire the final ranking and selecting the most excellent one. The paper by Tupenaite et. al. [12] described the notion of the incorporated analysis of built and human environment overhaul. Karabasevic et. al. [13] developed a structure for the assortment of employees depending on the methods of SWARA and ARAS methods under qualms and the usability and efficiency of the projected framework of the selection of contender for the position of the sales manager. Thus, the material selection can be considered as a MCDM problem for which a rational and organized material selection approach is required for identifying the best alternative. The main chore is contrasting the possessions of a realistic set of alternative materials and selecting the best one. A competent and ordered approach, based on some strong mathematical establishment, is thus required to make sure the amalgamation between designing and manufacturing industries.

Based on the literature review, it is found that very few researches has been carried for manufacturing and design material selection problems using different mathematical and MCDM-based methods of a maglev based car. In this paper, an effort is made to compare the ranking performances of COPRAS and ARAS methods for manufacturing and designing a maglev car using proper material selection under a given manufacturing arena. These two MCDM methods have very partial applications in the material selection domain. These MCDM methods have very high impact on complex manufacturing decision-making problems.

2. Complex Proportional Assessment Method

The COPRAS method provides a direct proportional criteria and utility degree of the existing options under the existence of reciprocally conflicting criteria and corresponding criteria weights [14,15]. It is used here for decision making which has a six stage procedure for ranking and evaluating alternatives in stipulations of their significance and utility degree. Table 1 depicts the material library and its nomenclature. Both positive (beneficial) and negative (non-beneficial) criteria are assessed separately as given in Table 2. It is better than the other methods as it can be used to calculate the utility degree of alternatives indicating the extent where one option is better or worse than other alternatives taken for comparison. Table 3 represents the quantitative data of analyzing the best material using COPRAS and ARAS. The steps are shown below:

Step 1: The decision matrix is normalized using linear normalization procedure [14,15] as given in Table 4 to acquire dimensionless values of dissimilar criteria and compared.

Step 2: The weighted normalized decision matrix, *D* is determined as given in Table 6.

$$D = [Y_{ij}]_{m \times n} = r_{ij} \times w_j \qquad (i = 1,2,3,\ldots,m;\ j = 1,2,3,\ldots,n) \tag{1}$$

Table 8 represents that the summation of all weighted normalized values (dimensionless) of each criterion identical to its weight.

$$\sum_{i=1}^{m} Y_{ij} = w_j \tag{2}$$

Thus, the weight, w_j of j^{th} criterion is comparatively disseminated to all the alternatives according to their weighted normalized value, Y_{ij}.

Step 3: The sums of Y_{ij} are calculated for both the beneficial and non-beneficial attributes using the following equations:

$$S_{+i} = \sum_{j=1}^{n} Y_{+ij} \tag{3}$$

$$S_{-i} = \sum_{j=1}^{n} Y_{-ij} \tag{4}$$

The greater the value of S_{+i}, the better is the alternative; and the lower the value of S_{-i}, the better is the alternative. S_{+i} and S_{-i} are always identical to the summation of weights for the beneficial and non-beneficial attributes as expressed by the following equations:

$$S_{+} = \sum_{i=1}^{m} S_{+i} = \sum_{i=1}^{m} \sum_{j=1}^{n} Y + ij \tag{5}$$

$$S_{-} = \sum_{i=1}^{m} S_{-i} = \sum_{i=1}^{m} \sum_{j=1}^{n} Y - ij \tag{6}$$

Step 4: The significances of the alternatives on the basis of defining the positive alternatives S_{+i} and negative alternatives S_{-i} characteristics are determined.

Step 5: The relative significances or priorities (Q_i) of the alternatives are calculated below:

$$Q_i = S_{+i} + \frac{S_{-\min} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} (S_{-\min} / S_{-i})} \qquad (i = 1, 2, 3, \ldots\ldots\ldots, m) \tag{7}$$

where S_{-min} is the minimum value of S_{-i}. When Q_i is greater, then the priority of the alternative is also higher. The highest relative significance value (Q_{max}) is the best selection among all the alternatives.

Step 6: Then the quantitative utility (U_i) for i^{th} alternative are obtained which leads to a complete ranking, is computed by comparing the priorities of all the alternatives with the most competent one and can be denoted as below:

$$U_i = [\frac{Q_i}{Q_{max}}] \times 100\% \quad (8)$$

where Q_{max} is the maximum relative significance value. Utility values range from 0-100 %. Table 9 represents Q_i and U_i values for Maglev materials. COPRAS hence directly evaluates the proportional dependencies of significances and utility degrees of the considered alternatives in a decision making problem having multiple criteria, their weights and performances comparative to all the criteria. By following the above steps the best material is obtained by ranking and material number A9 is found to be rank 1 which is AA7075 in COPRAS (Fig. 1).

3. Additive Ratio Assessment Method

The ARAS method is the perceptible measurements and utility theory where a utility function value designates the relative efficiency of various alternatives. It is directly proportional to the relative result of the criteria values and weightage parameters of the criteria. Table 1 shows the nomenclature of the 10 smart materials selected for ARAS. The steps of ARAS method are as follows:

Step 1: A definite normalization process with the normalized matrix as shown in Table 5 is proposed for the beneficial attributes and reciprocal of all the criteria is considered for non-beneficial attributes and hence the normalized decision matrix is determined with respect to all the alternatives [15]:

$$X_{ij}' = \frac{1}{X_{ij}} \quad (9)$$

Step 2: The normalized values are calculated:

$$R = [r_{ij}]_{m \times n} = \frac{X_{ij}'}{\sum_{i=1}^{m} X_{ij}'} \quad (10)$$

Then the weighted normalized decision matrix, D is determined (Table 7):

$$D = [Y_{ij}]_{m \times n} = r_{ij} \times w_j \qquad (i = 1,2,3,....,m;\ j = 1,2,3,....,n) \quad (11)$$

Step 3: The optimality function (S_i) for ith alternative is hence determined:

$$S_i = \sum_{j=1}^{n} Y_{ij} \quad (12)$$

Higher the S_i value, the better is the alternative, which is directly proportional to the decision matrix values and criteria weights.

Step 4: The degree of utility (U_i) is computed for each alternative and compared with the maximum efficient alternative (S_0). The equation for calculating utility degree (U_i) is given below:

$$U_i = \frac{S_i}{S_o} \quad (13)$$

Table 10 represents S_i and U_i values for the Maglev materials. The degree of utility of the alternatives varies from 0% to 100% and the one with the highest utility value (U_{max}) is the best choice (Rank 1) among all the alternatives. By following the above steps the best material is obtained by ranking and material number A9 is found to be rank 1 which is AA7075 in both the occasions (Fig. 1).

4. Results and Discussions

Magnetic Levitation is the main alternative to fuels, hence electromagnetism mechanism is proposed in this paper. Electromagnetism is process of creating magnetic field by running electric current through a copper wire. Hence, designing of solenoid, axle, chassis, propeller, body and wheels are mandatory. Electromagnetic coil is used which drags the piston to and fro effecting the cranking of the spindle rotating the axle in forward or backwards. The axle is being dwelled between two solenoid coils. When current flows in coil-1 the piston moves in forward direction pushing the bush-1 toggling the double pole double throw switch to change over the supply to the second coil-2. Again the piston-2 is hauled back resulting in backward direction. The current to the coils are given by the circuit through a relay which helps in energizing the coils at different timings affecting the difference in speed. Fig. 2 and Fig. 3 represent the parts and Catia design of the maglev car and Fig. 4 represents the detailed design flow diagram of the maglev car.

5. Cost Analysis

The idea of designing the maglev car must be cost effective, user friendly and the need for speed in the sustainable environment. Hence, estimated cost analysis is mandatory for the prototype development. It is made of solenoid round with copper wire and the permanent magnets which creates a high magnetic field to levitate and reduce the usage of fuel thus reducing pollution and developing a eco-green environment. A smart material (AA7075) has been used as maglev material. Table 11 represents the cost analysis as per recent market research of required items of maglev car which may be optimized further at lower cost.

6. Conclusions

The application expediency and accuracy of COPRAS and ARAS methods can be proved by solving a complex maglev material selection problem of designing a car. While applying COPRAS and ARAS methods to decision-making problems, a simple weighted summation technique is adopted separately for the normalized beneficial and non-beneficial attributes, leading to the calculation of an overall significance or utility of the considered alternatives. The main variation between the operational procedures of COPRAS and ARAS methods lies in the way they normalize the decision matrix. In COPRAS, a straightforward linear normalization is adopted, whereas, in ARAS method, a two step linear normalization technique is used. Both are relatively flexible and simple to understand, also segregates the subjective part of the decision-making process into criteria weights including decision makers' preferences. Both the two methods can be proficiently used to any type of industrial material selection problems involving any number of qualitative and quantitative criteria.

In this paper a maglev car has been designed with using a smart material (AA7075) which includes electromagnetic circuit to produce reciprocating motion. The levitating force calculation and limitation is essential for the power transmission of the maglev car. The introduction of steering mechanism can be included to front axle and also how to control the speed of the vehicle depending on requirement of operator. Selecting the exact size of the coil to run the vehicle depending on loading conditions needs finite element analysis which can be done in future. The design conditions can be improved and hence the cost can be optimized.

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Tables

Table 1. Material Library

MATERIAL	**MAT. No.**	**CRITERIA**	**Cr. No.**
AA1050	A1	Proof stress (Mpa)	PS
AA2011	A2	Tensile strength (Mpa)	TS
AA5083	A3	Shear strength (Mpa)	SS
AA5251	A4	Elongation (%)	EL
AA5754	A5	Brinell Hardness	BH
AA6063	A6	Fatigue Endurance Limit (MPa)	FEL
AA6082	A7		
AA6262	A8		
AA7075	A9		
Low Carbon Steel	A10		

Table 2. Beneficial and non-beneficial criteria

BENEFICIAL	NON BENEFICIAL
PS	EL
TS	
SS	
BH	
FEL	

Table 3. Quantitative Data [https://www.azom.com/article.aspx?ArticleID=2863]

MAT. No.	PS	TS	SS	EL	BH	FEL
A1	140	150	85	6	43	100
A2	315	420	250	13	115	250
A3	370	420	230	5	115	280
A4	270	310	165	5	90	250
A5	300	340	190	5	95	280
A6	240	260	155	9	80	150
A7	310	340	210	11	95	210
A8	330	360	240	3	120	90
A9	505	570	350	10	150	300
A10	103	402	339	15	69.8	100

Table 4. Normalized Matrix (COPRAS)

MAT. No.	PS	TS	SS	EL	BH	FEL
A1	0.0486	0.0420	0.0384	0.0732	0.0442	0.0498
A2	0.1093	0.1176	0.1129	0.1585	0.1182	0.1244
A3	0.1283	0.1176	0.1039	0.0610	0.1182	0.1393
A4	0.0937	0.0868	0.0745	0.0610	0.0925	0.1244
A5	0.1041	0.0952	0.0858	0.0610	0.0977	0.1393
A6	0.0832	0.0728	0.0700	0.1098	0.0822	0.0746
A7	0.1075	0.0952	0.0949	0.1341	0.0977	0.1045
A8	0.1145	0.1008	0.1084	0.0366	0.1234	0.0448
A9	0.1752	0.1596	0.1581	0.1220	0.1542	0.1493
A10	0.0357	0.1125	0.1531	0.1829	0.0718	0.0498

Table 5. Normalized Matrix (ARAS)

MAT. No.	PS	TS	SS	EL	BH	FEL
A1	0.0486	0.0420	0.0384	0.1078	0.0442	0.0498
A2	0.1093	0.1176	0.1129	0.0498	0.1182	0.1244
A3	0.1283	0.1176	0.1039	0.1294	0.1182	0.1393
A4	0.0937	0.0868	0.0745	0.1294	0.0925	0.1244
A5	0.1041	0.0952	0.0858	0.1294	0.0977	0.1393
A6	0.0832	0.0728	0.0700	0.0719	0.0822	0.0746
A7	0.1075	0.0952	0.0949	0.0588	0.0977	0.1045
A8	0.1145	0.1008	0.1084	0.2157	0.1234	0.0448
A9	0.1752	0.1596	0.1581	0.0647	0.1542	0.1493
A10	0.0357	0.1125	0.1531	0.0431	0.0718	0.0498

Table 6. Weighted Normalized Matrix (COPRAS)

MAT. No.	PS	TS	SS	EL	BH	FEL
A1	0.0086	0.0046	0.0057	0.0187	0.0047	0.0100
A2	0.0193	0.0128	0.0168	0.0406	0.0126	0.0249
A3	0.0227	0.0128	0.0155	0.0156	0.0126	0.0279
A4	0.0166	0.0095	0.0111	0.0156	0.0099	0.0249
A5	0.0184	0.0104	0.0128	0.0156	0.0104	0.0279
A6	0.0147	0.0079	0.0104	0.0281	0.0088	0.0149
A7	0.0190	0.0104	0.0141	0.0343	0.0104	0.0209
A8	0.0203	0.0110	0.0162	0.0094	0.0132	0.0090
A9	0.0310	0.0174	0.0236	0.0312	0.0165	0.0299
A10	0.0063	0.0123	0.0228	0.0468	0.0077	0.0100

Table 7. Weighted Normalized Matrix (ARAS)

MAT. No.	PS	TS	SS	EL	BH	FEL
A1	0.0086	0.0046	0.0057	0.0276	0.0047	0.0100
A2	0.0193	0.0128	0.0168	0.0127	0.0126	0.0249
A3	0.0227	0.0128	0.0155	0.0331	0.0126	0.0279
A4	0.0166	0.0095	0.0111	0.0331	0.0099	0.0249
A5	0.0184	0.0104	0.0128	0.0331	0.0104	0.0279
A6	0.0147	0.0079	0.0104	0.0184	0.0088	0.0149
A7	0.0190	0.0104	0.0141	0.0151	0.0104	0.0209
A8	0.0203	0.0110	0.0162	0.0552	0.0132	0.0090
A9	0.0310	0.0174	0.0236	0.0166	0.0165	0.0299
A10	0.0063	0.0123	0.0228	0.0110	0.0077	0.0100

Table 8. Sum of Weighted Normalized Values (COPRAS)

MAT. No.	S_{+i}	Value	S_{-i}	Value
A1	S_{+1}	0.0336	S_{-1}	0.0187
A2	S_{+2}	0.0865	S_{-2}	0.0406
A3	S_{+3}	0.0915	S_{-3}	0.0156
A4	S_{+4}	0.0719	S_{-4}	0.0156
A5	S_{+5}	0.0799	S_{-5}	0.0156
A6	S_{+6}	0.0568	S_{-6}	0.0281
A7	S_{+7}	0.0749	S_{-7}	0.0343
A8	S_{+8}	0.0696	S_{-8}	0.0094
A9	S_{+9}	0.1183	S_{-9}	0.0312
A10	S_{+10}	0.0590	S_{-10}	0.0468

Table 9. Q_i and U_i values for Maglev materials (COPRAS)

MAT. No.	Q_i	U_i	RANK
A1	0.0612	45.4	10
A2	0.0992	73.6	6
A3	0.1247	92.4	3
A4	0.1050	77.9	5
A5	0.1130	83.8	4
A6	0.0752	55.8	8

A7	0.0899	66.7	7
A8	0.1248	92.5	2
A9	0.1349	100.0	**1**
A10	0.0701	51.9	9

Table 10. S_i and U_i values for Maglev materials (ARAS)

MAT. No.	**S_i**	**U_i**	**RANK**
A1	0.0612	0.454	10
A2	0.0992	0.736	6
A3	0.1246	0.924	3
A4	0.1050	0.779	5
A5	0.1130	0.838	4
A6	0.0752	0.558	8
A7	0.0899	0.667	7
A8	0.1248	0.925	2
A9	0.1349	1.000	**1**
A10	0.0701	0.519	9

Table 11. Cost analysis of the required items of the Maglev Car

SL.No.	**Parts**	**Particulars**	**Quantity**	**Estimated Cost in INR**
1	Maglev Material	AA7075	500g	125
2	Copper Wire	Copper	200 gm	80
3	Battery	1.5V	2 Pc	72
4	Ferro magnet	Magnet Material	1 Pc	12
5	Propeller	Plastic	1 Pc	90
6	Permanent Magnet	Neodymium	2 Pcs	200
7	Toy Car	Plastic	1Pc	500
Total Cost				**1079 /-**

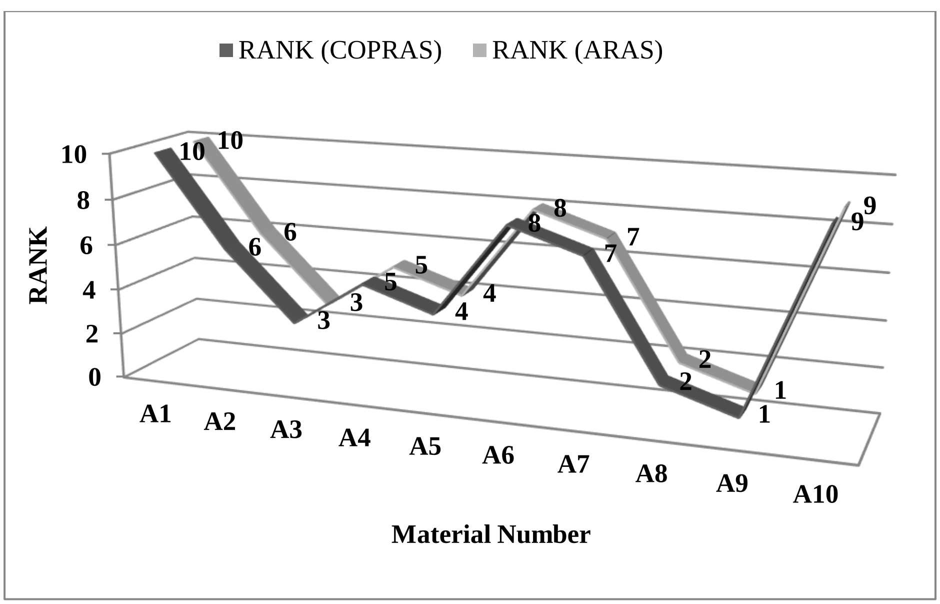

Fig. 1 Rank of Maglev material using COPRAS and ARAS

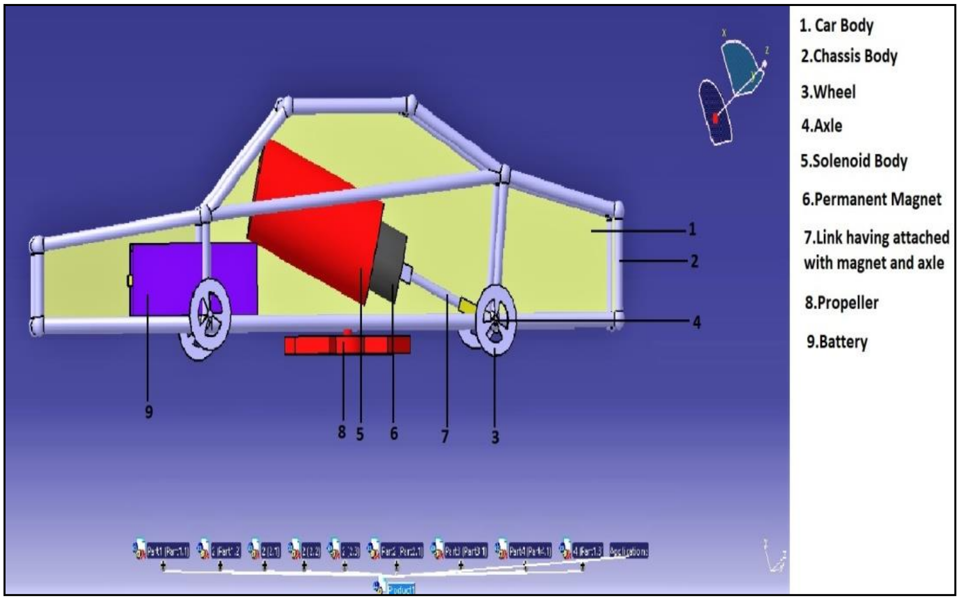

Fig. 2 Parts of Maglev Car

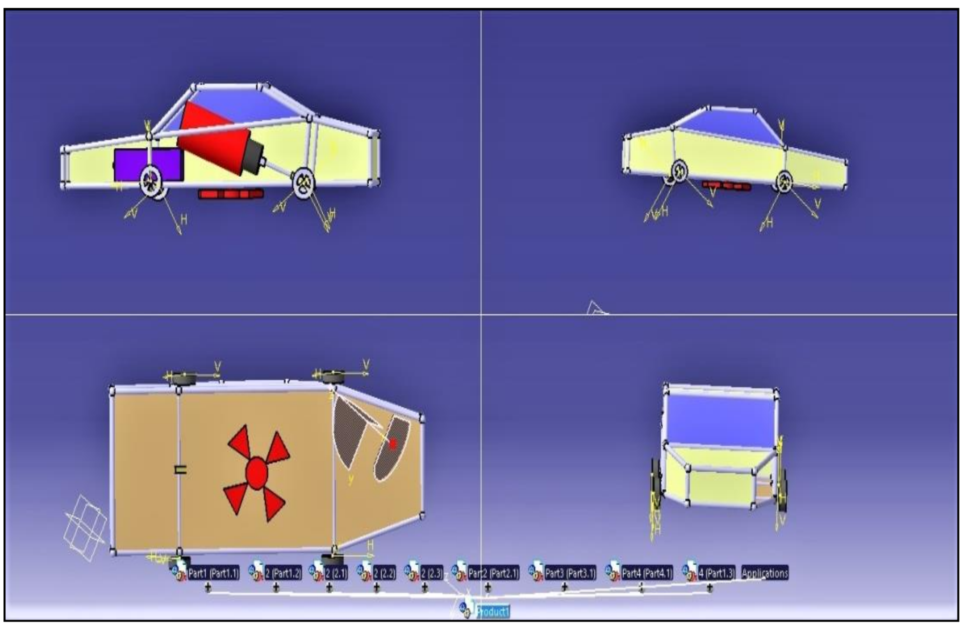

Fig. 3 Catia Design and all views of Maglev Car

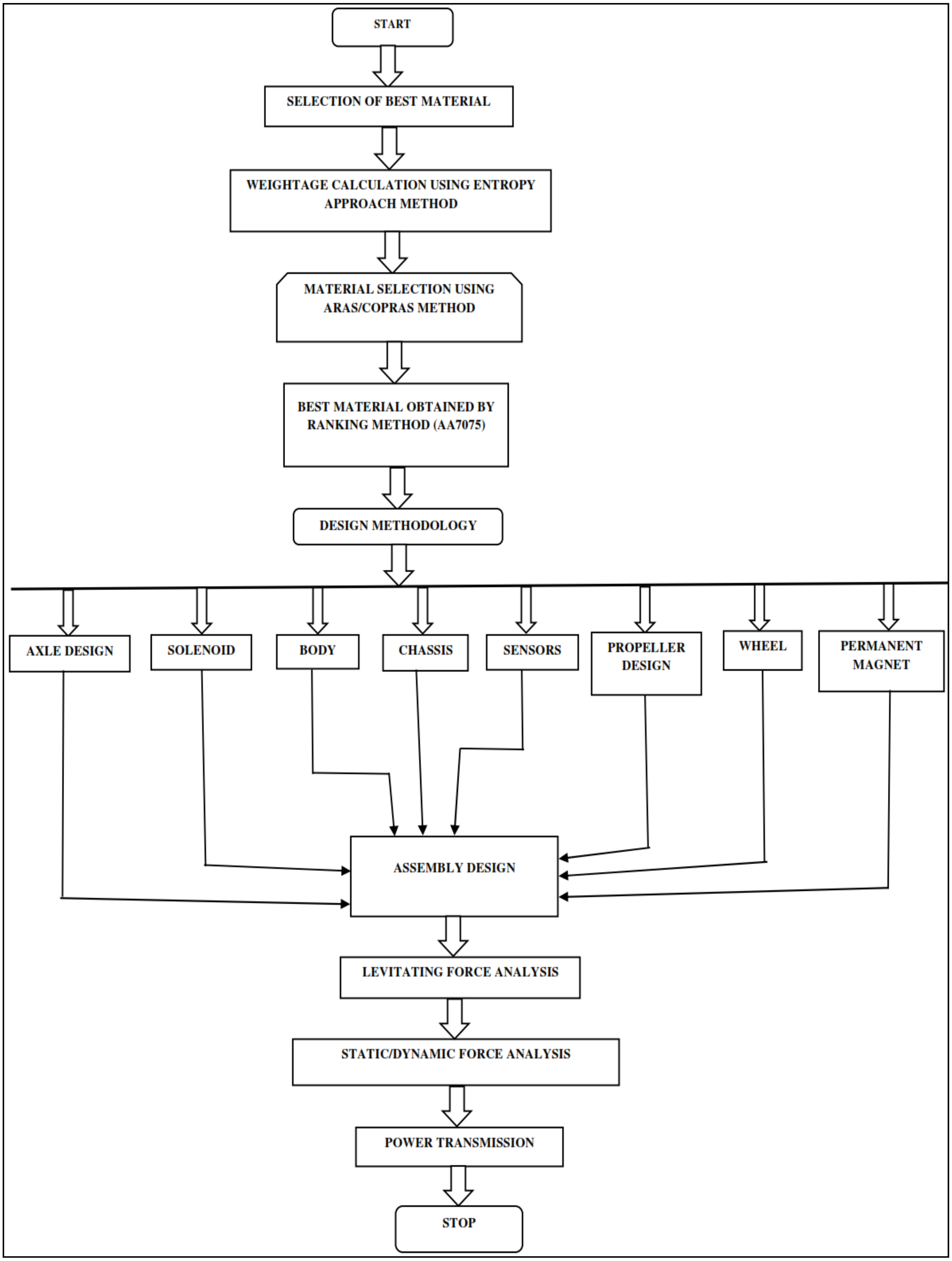

Fig. 4 Design Flow diagram of Maglev Car