

Automobile Tire Assessment: A Multi-Criteria Approach

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Abstract—In response to the present dynamic market, automobile manufacturing industries are constantly evaluating and improving their manufacturing strategies to stay competitive. It is also evident that they evaluate those strategies considering multiple criteria. In one such case, an automobile project manager has to ensure that the selected tire (among the available alternatives) complies with the prospective automobile's performance. This paper presents an approach for the assessment of alternative automobile tires taking into account multiple criteria, such as tire sustainability, tire road performance, environmental issues, tire purchase cost and tire road grip. The presented approach is quite helpful to any decision maker who is interested not only in ranking alternatives but also in establishing the superiority of an alternative over others. The approach also helps to specify the position of each alternative with respect to ideal solution. A case illustration is used to demonstrate an application of the approach.

Keywords—automobile tire; multi-criteria; decision making

I. INTRODUCTION

In the tire market, there is a wide variety of tires for light & heavy automobiles. Therefore, the justification of tire choice is an important and a crucial issue. Thus, in response to the present dynamic market and green ecofriendly need, automobile manufacturing industries are constantly evaluating and improving their vendor selection strategies to stay competitive. Nowadays, the automobile sector is receiving much attention from the research community. As tires play an important role in an automobile's performance, an automobile manufacturer has to select tires that are correctly sized and rated for its automobile to fulfill a fundamental set of criteria, such as load-carrying capacity, cushioning, dampening, braking torque, cornering force, dimensional stability, steering response, rolling resistance, and expected life span [1-3]. Researchers also highlighted that elongation and tensile strength of the tire are important as quality control criteria in evaluating automobile road performance [4, 5].

From the open source database, it is clear that there is an enormous increase in major road accidents. A significant contributing factor to these accidents is tire failure. A field investigation of eight different brands of tires to understand the reasons for tire failure was reported in [4]. For example, catastrophic separation and tire blowouts are common events directed to serious road accidents [6]. Tire blowouts are

extremely a safety issue concern. Close to 13% of road accidents reported are attributed to tire failure [7]. Hence, one of the issues faced by the automobile research and development department is to test the alternative tires on multiple measures. The present paper attempts to present an approach to assess alternative automobile tires taking into account multiple criteria, such as tire sustainability, tire road performance, environmental issues, tire purchase cost and tire road grip. A case study is presented to show an application of the approach.

II. MULTI-CRITERIA DECISION MAKING: A REVIEW

Multi-criteria decision-making approaches are widely used in service and manufacturing industries. Any decision-making approach concerned with the task of ranking a set of finite alternatives. Researchers [8-9] have reviewed common multi-criteria decision making approaches and examined the advantages and disadvantages and also explained the relative strengths and weaknesses. Some of the multi-criteria decision-making approaches use additive formulas to classify the alternatives on hand. The summary of the most commonly used multi-criteria decision-making methods presented below:

- Analytic Hierarchy Process (AHP): A multi-criteria decision making approach introduced in [10]. The approach needs the decision tree with the goal at the top-level, criteria and sub-criteria in middle levels, and the alternatives at the bottom. In AHP, the experts and decision makers do pair-wise comparison and select the best alternative according to the highest rank between alternatives. The drawback of the approach is that its unidirectional relationship characteristic cannot handle the complexity of many problems.
- Analytic Network Process (ANP): The ANP method is a general form of the AHP, ANP introduced in [9]. ANP partly overcomes the drawback of AHP and deals with the problem as a network of complex relationships between alternatives and criteria where all elements are connected [11].
- Preference ranking organization method for enrichment evaluation (PROMETHEE): This method uses the positive and negative outranking flows to rank the alternatives. These outranking flows do not usually induce the same rankings. Subsequently, the approach considers the net outranking flow to do a pair-wise comparison of

alternatives to rank them with respect to multiple criteria [12].

- The elimination and choice translating reality (ELECTRE): The ELECTRE approach focused on the dominance relations between alternatives. It is based on outranking relationships, and uses thresholds of indifference & preference to do pair-wise comparison between alternatives [13]. As the approach incorporates the fuzzy nature of decision-making, decision makers prefer the ELECTRE approach over the other approaches.
- The technique for order preference by similarity to ideal solutions (TOPSIS): This approach is based on the concept that the selected alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The approach demarcates the positive ideal and negative ideal solutions. In this approach, the Euclidean distance approach is used to check the relative closeness of the alternatives to the ideal solution [14-15].

In general, multi-criteria decision-making approaches have the following basic steps [15]: (a) Formulate of the decision tree using alternatives, criteria and sub-criteria (b) Determine the relative importance of the criteria and the impacts of the alternatives on these criteria. (c) Process the numerical values to find a ranking of each alternative. Apply value judgment on acceptable tradeoffs and evaluation, and (d) calculate final ranking and make decision.

Researchers and practitioners have adopted multi-criteria decision analysis in some industrial applications, such as in manufacturing technology investment decisions [16], for evaluation of energy plans [6] and for manufacturing non-financial justification [17]. In particular, automobile researchers adopted multi-criteria decision approach to select suitable tires for two-wheel drive tractors operating in sandy clay loam soils [18]. An intelligent tire model derived that can show the relationships between driving conditions and tire strain [19]. Similarly, a qualitative formula developed to estimate the tire wear [20].

III. COMPARATIVE ASSESSMENT : AN APPROACH

An integrated multi criteria approach for an automobile tire assessment presented here in this section. The approach evaluates the decision hierarchy and derives weights for each criteria and sub-criteria using AHP [9-10] (refer steps 1 to 3). These weights are further used to do comparative assessment using TOPSIS approach [14-15] (refer steps 4 to 9). The details about each step and calculations involved are presented here below.

Step 1: Develop the decision hierarchy

The approach needs a decision hierarchy, with the goal at the top-level, the criteria and the sub-criteria (attributes) in middle levels, and the alternatives at the bottom. Figure 1 illustrates the decision hierarchy.

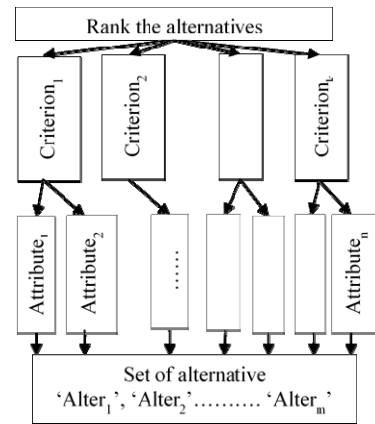


Fig. 1. The decision hierarchy

Step 2: Do pairwise comparisons of criteria and attributes

It is recommended that these pairwise comparisons be carried out using verbal responses and or non-verbal responses [10]. For example, the decision maker asked to answer whether Criterion₁ and Criterion₂ are of equal importance or whether one is more important than the other. If he/she indicates that Criterion₁ is more important, later he/she has to specify is Criterion₁: weakly more important, strongly more important, very strongly more important or extremely more important?

Resulted set of comparisons expressed in the form of criteria comparative matrix (CCM) as given below.

$$CCM = \begin{bmatrix} \text{Criteria} \downarrow \rightarrow & C_1 & C_2 & \dots & C_k & \dots & C_l \\ C_1 & 1 & x & \dots & \dots & \dots & \dots \\ C_2 & 1/x & 1 & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ C_k & \dots & \dots & \dots & 1 & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & 1 & 1/y \\ C_l & \dots & \dots & \dots & \dots & y & 1 \end{bmatrix} \quad (1)$$

In the above matrix, the criterion C₁ is x times more important than criterion C₂. Similarly, do pairwise comparison for group of attributes for a given criterion. Resulted set of comparisons expressed in the form of attribute comparative matrix (ACM) as below.

$$ACM = \begin{bmatrix} \text{Attrb} \downarrow \rightarrow & A_1 & A_2 & \dots & A_j & \dots & A_n \\ A_1 & 1 & z & \dots & \dots & \dots & \dots \\ A_2 & 1/z & 1 & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ A_j & \dots & \dots & \dots & 1 & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ A_n & \dots & \dots & \dots & \dots & \dots & 1 \end{bmatrix} \quad (2)$$

In the above matrix, the attribute A₁ is z times more important than attribute A₂.

Step 3: Transform the pairwise comparisons of attributes into attributes weight:

After each comparison done, the obtained values converted by AHP process into a set of weights, which are then normalized. An approach based on eigenvalues is recommended [10]. Since this involves a relative complex mathematical procedure, software such as Super decision is used. These weights are subsequently used to get weighted normalized matrix. The normalized weights for attribute (W_j) expressed as (3).

$$W_j = [W_1 \ W_2 \ \dots \ W_{n-1} \ W_n] \text{ for attributes } (3)$$

Step 4: Establish decision matrix and calculate normalized decision matrix:

Qualitative and quantitative data for given alternatives expressed as decision matrix (DM) as given below.

$$DM = \begin{bmatrix} \swarrow \rightarrow & A_1 & \dots & A_j & \dots & A_n \\ \text{Alter}_1 & X_{11} & \dots & \dots & \dots & X_{1n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_i & X_{i1} & \dots & X_{ij} & \dots & X_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_m & X_{m1} & \dots & \dots & \dots & X_{mn} \end{bmatrix} \quad (4)$$

In the above matrix (4) 1 to m are alternatives and 1 to n are the attributes. X_{11} represents data entry for an alternative (Alter_1) with respect to an attribute (A_1). This information is further treated as a decision matrix and transformed into the normalized decision matrix (NDM). The NDM represents relative performance of existing alternatives and represented in matrix form as.

$$NDM = \begin{bmatrix} i \swarrow j \rightarrow & A_1 & \dots & A_j & \dots & A_n \\ \text{Alter}_1 & R_{11} & \dots & \dots & \dots & R_{1n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_i & R_{i1} & \dots & R_{ij} & \dots & R_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_m & R_{m1} & \dots & \dots & \dots & R_{mn} \end{bmatrix} \quad (5)$$

The NDM data obtained using DM and (6).

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_i X_{ij}^2}} \quad (6)$$

In (6), X_{ij} is measured value of alternative i with respect to attribute j and R_{ij} is the normalized score for alternative i w.r.t attribute j.

Step 5: Construct the weighted normalized decision matrix:

This step uses of set of criteria and attributes weight obtained at step 3. Thus the normalized decision matrix value R_{ij} is converted into the weighted normalized. The WDM data is obtained using (8).

Step 6: Establish the ideal and negative ideal solution:

Let J_{\max} be the set of attributes (where preference is ‘maximum value’) and J_{\min} be the set of negative attributes (where preference is ‘minimum value’). The positive ideal solution set expressed as (9).

$$WDM = \begin{bmatrix} i \swarrow j \rightarrow & A_1 & \dots & A_j & \dots & A_n \\ \text{Alter}_1 & V_{11} & \dots & \dots & \dots & V_{1n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_i & V_{i1} & \dots & V_{ij} & \dots & V_{in} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_m & V_{m1} & \dots & \dots & \dots & V_{mn} \end{bmatrix} \quad (7)$$

$$V_{ij} = W_j \times R_{ij} \quad (8)$$

$$V^* = \{V_1^*, V_2^*, \dots, V_j^*, \dots, V_n^*\} \quad (9)$$

In (9),

$$V_j^* = \{\max V_{ij} \text{ if } (j \in J_{\max}) \text{ or } \min V_{ij} \text{ if } (j \in J_{\min})\}$$

The negative ideal solution set expressed as below.

$$V' = \{V_1', V_2', \dots, V_j', \dots, V_n'\} \quad (10)$$

Where $V_j' = \{\min V_{ij} \text{ if } (j \in J_{\max}) \text{ or } \max V_{ij} \text{ if } (j \in J_{\min})\}$

Step 7: Establish the separation measures for each alternative:

The separation measure for an alternative from the ideal alternative S_i^* is established using (11).

$$S_i^* = \left[\sum_j (V_j^* - V_{ij})^2 \right]^{1/2} \quad (11)$$

Similarly, the separation measure for an alternative from the worst alternative S_i' is established using (12).

$$S_i' = \left[\sum_j (V_j' - V_{ij})^2 \right]^{1/2} \quad (12)$$

In above (11) and (12), the number of alternatives varies from 1 to m, V_{ij} is weighted normalized data for an alternative i with respect to an attribute j.

Step 8: Establish the relative closeness of an alternative with respect to the ideal solution:

The closeness measure C_i^* for an alternative with respect to the ideal alternative established using (13).

$$C_i^* = \frac{S_i'}{(S_i^* + S_i')} \quad (13)$$

Where, S_i^* is the separation measure for an alternative from the ideal alternative, and S_i' is the separation measure for an alternative from the worst alternative and while, C_i^* is the closeness measure. Note C_i^* satisfies $0 < C_i^* < 1$. The obtained values of V_{ij} , V_j^* , V_j' , S_i^* , S_i' and C_i^* in matrix form as closeness matrix (CM) (refer to (14)).

Step 9: Select the best alternative:

Finally the alternatives ranked in descending order based on closeness value C_i^* .

$$CM = \begin{bmatrix} i \downarrow j \rightarrow & A_1 & A_2 & \dots & A_n & S_i^* & S_i' & C_i^* \\ \text{Alter}_1 & V_{11} & V_{12} & \dots & V_{1n} & S_1^* & S_1' & C_1^* \\ \text{Alter}_2 & V_{21} & V_{22} & \dots & V_{2n} & S_2^* & S_2' & C_2^* \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \text{Alter}_m & V_{m1} & V_{m2} & \dots & V_{mn} & S_m^* & S_m' & C_m^* \\ V_j^* & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ V_j' & \dots & \dots & \dots & \dots & \dots & \dots & \dots \end{bmatrix} \quad (14)$$

IV. APPLICATION OF THE APPROACH

At the start the general goal was stated as ‘to rank the available alternative tires’. There were five criteria considered such as tire sustainability (TSU), tire performance (TP), tire grip (TG), tire environmental hazard (TEH) and tire cost (TC). As shown in Figure 2, these criteria were further fragmented down into attributes at next level. For example, criterion tire sustainability, the attributes tire carrying load capacity (TLC), tire cushioning, and tire long lasting (TLL) quantified. Similarly, for criterion tire performance, the attributes tire thread depth (TTD) and tire maximum speed (TS) measured. Whereas, for criterion tire environmental hazard, the attributes tire noise pollution (TNP) and tire rolling resistance (TRR) measured. And, for criterion tire grip, the attributes such as tire dry grip (TDG) and tire wet grip (TWG) scores obtained. Finally, the alternatives added in the lower level to the hierarchy.

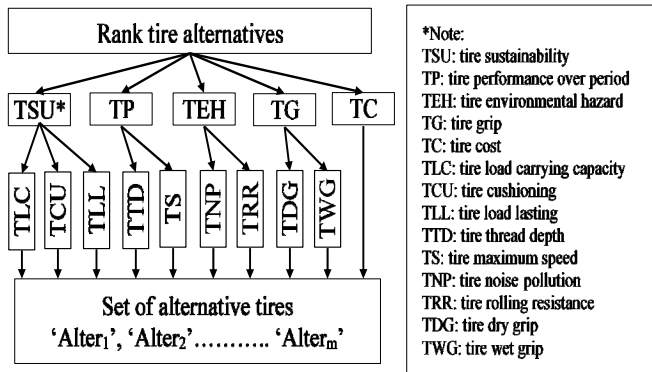


Fig. 2. Automobile tire decision hierarchy

Pairwise comparisons carried out using quantitative and qualitative responses. For example, in order to assess whether TSU and TP criteria had equal importance or whether one was more important than the other. If the professional indicated that TP was more important, then he was later asked if the TP was weakly more important, strongly more important, very strongly more important, or extremely more important. Likewise, pairwise comparisons were carried out.

The obtained pairwise comparative data expressed (refer to (1)) as in the form of criteria comparative matrix (CCM). In the following CCM matrix, the TSU quantified 3 times more important than criterion TP. Subsequently, decision makers asked to do pairwise comparison of attributes for each criterion.

The outcome of experts’ opinion expressed (refer to (2)) as ACM matrix.

$$CCM = \begin{bmatrix} \text{Criteria} \downarrow \rightarrow & \text{TSU} & \text{TP} & \text{TEH} & \text{TG} & \text{TC} \\ \text{TSU}^* & 1 & 3 & 4 & 2 & 2 \\ \text{TP} & 0.33 & 1 & 2 & 0.5 & 0.33 \\ \text{TEH} & 0.25 & 0.5 & 1 & 0.5 & 0.33 \\ \text{TG} & 0.5 & 2 & 2 & 1 & 2 \\ \text{TC} & 0.5 & 3 & 3 & 0.5 & 1 \end{bmatrix}$$

$$ACM = \begin{bmatrix} \text{for TSU}^* & \text{TLC} & \text{TCU} & \text{TLL} \\ \text{TLC} & 1 & 3 & 0.5 \\ \text{TCU} & 0.33 & 1 & 0.33 \\ \text{TLL} & 2 & 3 & 1 \end{bmatrix} \begin{bmatrix} \text{for TEH} & \text{TNP} & \text{TRR} \\ \text{TNP} & 1 & 0.5 \\ \text{TRR} & 2 & 1 \end{bmatrix}$$

$$ACM = \begin{bmatrix} \text{for TG} & \text{TDG} & \text{TWG} \\ \text{TDG} & 1 & 3 \\ \text{TWG} & 0.33 & 1 \end{bmatrix} \begin{bmatrix} \text{for TP} & \text{TTD} & \text{TS} \\ \text{TTD} & 1 & 2 \\ \text{TS} & 0.5 & 1 \end{bmatrix}$$

*Refer to Figure 2

The cell values in the above set of matrices represent pairwise comparison of attributes for the given criterion. As presented, decision makers stated that for the given criterion TSU, the attribute TLC was three-time more important than TCU, and while TLL was three times more important than TCU and two times more important than TLC. After pairwise comparison of attribute, the obtained scores converted into normalized weights (refer to (3)). The obtained normalized weights were as:

$$W_j = \begin{bmatrix} \text{TLC} & \text{TCU} & \text{TLL} & \text{TNP} & \text{TRR} & \text{TTD} & \text{TS} & \text{TDG} & \text{TWG} & \text{TC} \\ 0.0807 & 0.0337 & 0.1228 & 0.0809 & 0.1619 & 0.1619 & 0.0809 & 0.1823 & 0.0607 & 0.0288 \end{bmatrix}$$

Table I presents the list of the alternative tires. It highlights the performance of alternative tires aligned with multiple criteria and their attributes. As presented in Table I, qualitative and quantitative data for given alternatives expressed (refer to (4)) as decision matrix (DM). It is clear that each attributes have different dimensions to measure. There is a need to transform various attribute dimensions into non-dimensional attributes, and to do neutral comparisons across criteria and attributes. The obtained outcome is presented in Table II. Taking into account each of these normalize decision matrix and attribute weights for each alternative, weighted normalized decision matrix derived using (9), the derived outcome is as presented in Table III. Subsequently, attributes categorized into two sets as V_j^* and V_j' , the set of maximization attributes and minimization attributes.

In Table III, W_j is weight for attribute j , V_j^* is ideal solution for attribute j , and V_j' is negative ideal solution for attribute j . Subsequently, to perform the sensitivity analysis, in the presented approach different set of weights used (Table IV). The separation measure for all alternative tires and their closeness value with respect to the best and worst solution obtained and corresponding closeness score C_i^* for each alternative presented in Table V. Subsequently, these alternative tires are ranked based on closeness score C_i^* . In

Table V, S_i^* is separation measure for given alternative i from ideal alternative, S_j is separation measure for given alternative i from negative ideal alternative and C_i^* is closeness measure for alternative i .

TABLE I. INPUT DATA FOR ASSESSMENT OF ALTERNATIVE TIRES

Tire Codes	TSU*			TP		TEH		TC	TG	
	TLC	TCU	TLL	TTD	TS	TNP	TRR	TC	TDG	TWG
	max# kg	max scale	max months	max mm	max Km/hr	min ratio	min ratio	min \$	max %	max %
T01	1060	3	12	8.2	180	5.5	18	5	91.8	54
T02	1090	5	30	9	200	2	12	3	95.2	58
T03	1120	4	24	9	200	4	14	5	94.5	57.5
T04	1060	2	18	8.4	190	6	16	5	92	53
T05	1090	3	20	8.6	200	5.5	18	3	91.5	55
T06	1090	4	20	8.6	210	3	14	2	92.7	58.8
T07	1000	4	24	8.6	200	3	13	2	93	56.5
T08	1060	3	18	8.4	170	5	17	3	90	53.2
T09	1090	5	30	8.6	190	3.5	15	5	95.8	56
T10	1060	4	20	8.8	210	2.5	13	1	95	57
T11	925	3	18	8.4	210	6	18	4	89	53
T12	1120	4	18	8.8	210	4.5	12	3	93	55.7
T13	1120	5	24	9	180	3.5	16	2	94.5	56.7
TCU Score	Very good			Good	Satisfactory	Average		Below average		
	5			4	3	2		1		
TC Score	Above \$500		\$ 400 to 500		\$ 250 to 400		\$150 to 250		Below \$150	
	5		4		3		2		1	

Note: *Refer Figure 2, max: objective maximize, min: objective minimize

TABLE II. NORMALIZED SCORES FOR EACH ATTRIBUTE & ALTERNATIVE

Codes	TLC	TCU	TLL	TTD	TS	TNP	TRR	TC	TDG	TWG
T01	0.27	0.21	0.15	0.26	0.25	0.35	0.33	0.39	0.27	0.27
T02	0.28	0.36	0.38	0.29	0.28	0.13	0.22	0.23	0.28	0.29
T03	0.29	0.29	0.31	0.29	0.28	0.25	0.25	0.39	0.28	0.29
T04	0.27	0.14	0.23	0.27	0.27	0.38	0.29	0.39	0.27	0.26
T05	0.28	0.21	0.25	0.28	0.28	0.35	0.33	0.23	0.27	0.27
T06	0.28	0.29	0.25	0.28	0.30	0.19	0.25	0.16	0.28	0.29
T07	0.26	0.29	0.31	0.28	0.28	0.19	0.24	0.16	0.28	0.28
T08	0.27	0.21	0.23	0.27	0.24	0.32	0.31	0.23	0.27	0.26
T09	0.28	0.36	0.38	0.28	0.27	0.22	0.27	0.39	0.29	0.28
T10	0.27	0.29	0.25	0.28	0.30	0.16	0.24	0.08	0.28	0.28
T11	0.24	0.21	0.23	0.27	0.30	0.38	0.33	0.31	0.27	0.26
T12	0.29	0.29	0.23	0.28	0.30	0.29	0.22	0.23	0.28	0.28
T13	0.29	0.36	0.31	0.29	0.25	0.22	0.29	0.16	0.28	0.28

TABLE III. WEIGHTED NORMALIZED SCORES FOR EACH ATTRIBUTE & ALTERNATIVE

Codes	TLC	TCU	TLL	TTD	TS	TNP	TRR	TC	TDG	TWG
$W_j \rightarrow$	0.0807	0.0337	0.1282	0.1619	0.0809	0.0809	0.1619	0.0288	0.1823	0.0607
T01	0.022	0.007	0.020	0.043	0.021	0.028	0.053	0.011	0.050	0.016
T02	0.023	0.012	0.049	0.047	0.023	0.010	0.035	0.007	0.052	0.018
T03	0.023	0.010	0.039	0.047	0.023	0.021	0.041	0.011	0.051	0.017
T04	0.022	0.005	0.029	0.044	0.022	0.031	0.047	0.011	0.050	0.016
T05	0.023	0.007	0.033	0.045	0.023	0.028	0.053	0.007	0.050	0.017
T06	0.023	0.010	0.033	0.045	0.024	0.015	0.041	0.004	0.050	0.018
T07	0.021	0.010	0.039	0.045	0.023	0.015	0.038	0.004	0.051	0.017
T08	0.022	0.007	0.029	0.044	0.019	0.026	0.050	0.007	0.049	0.016
T09	0.023	0.012	0.049	0.045	0.022	0.018	0.044	0.011	0.052	0.017
T10	0.022	0.010	0.033	0.046	0.024	0.013	0.038	0.002	0.052	0.017
T11	0.019	0.007	0.029	0.044	0.024	0.031	0.053	0.009	0.048	0.016
T12	0.023	0.010	0.029	0.046	0.024	0.023	0.035	0.007	0.051	0.017
T13	0.023	0.012	0.039	0.047	0.021	0.018	0.047	0.004	0.051	0.017
V_j^*	0.023	0.012	0.049	0.047	0.024	0.010	0.035	0.002	0.052	0.018
V_j^-	0.019	0.005	0.020	0.043	0.019	0.031	0.053	0.011	0.048	0.016

TABLE IV. SET OF WEIGHTS USED FOR SENSITIVITY ANALYSIS

Weight Used	Attribute									
	TLC	TCU	TLL	TTD	TS	TNP	TRR	TC	TDG	TWG
AHP	0.0807	0.0337	0.1282	0.1619	0.0809	0.0809	0.1619	0.0288	0.1823	0.0607
Equal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Unequal	0.05	0.05	0.05	0.05	0.1	0.05	0.1	0.01	0.5	0.04

TABLE V. SEPARATION MEASURES AND RELATIVE CLOSENESS FOR EACH ALTERNATIVE TIRE FROM IDEAL SOLUTION AND RANK OF ALTERNATIVE TIRE

Tire Codes	if AHP weights were given to all attribute				if equal weights were given to all attribute				if unequal random weights were given to attributes			
	S_i^*	S_i'	C_i^*	Rank	S_i^*	S_i'	C_i^*	Rank	S_i^*	S_i'	C_i^*	Rank
T01	0.041	0.005	0.108	13	0.049	0.009	0.153	13	0.022	0.006	0.105	13
T02	0.005	0.042	0.899	1	0.016	0.045	0.743	1	0.002	0.025	0.856	1
T03	0.018	0.027	0.596	6	0.036	0.027	0.429	8	0.010	0.017	0.561	5
T04	0.033	0.012	0.268	11	0.049	0.010	0.165	12	0.021	0.008	0.259	10
T05	0.031	0.015	0.330	9	0.035	0.021	0.376	9	0.020	0.009	0.339	9
T06	0.019	0.026	0.580	7	0.018	0.037	0.668	5	0.010	0.017	0.589	6
T07	0.013	0.031	0.709	2	0.015	0.038	0.716	3	0.008	0.019	0.711	4
T08	0.030	0.013	0.298	10	0.034	0.020	0.371	10	0.020	0.007	0.311	11
T09	0.015	0.035	0.696	3	0.033	0.036	0.521	6	0.008	0.021	0.653	3
T10	0.017	0.029	0.633	4	0.015	0.044	0.742	2	0.008	0.020	0.647	2
T11	0.035	0.011	0.244	12	0.042	0.014	0.252	11	0.023	0.008	0.245	12
T12	0.024	0.024	0.497	8	0.028	0.028	0.500	7	0.012	0.017	0.497	8
T13	0.018	0.027	0.604	5	0.017	0.039	0.701	4	0.011	0.018	0.611	7

V. DISCUSSION

For an automobile project in Saudi Arabia, the goal set was to use a scientific multi criteria approach to make sure that the selected tire (among available alternatives) complies with prospective automobile performance. For the assessment of alternative automobile tires multiple criteria, such as tire sustainability, tire road performance, environmental issues, tire purchase cost and tire road grip are taken into account by the decision makers. The decision makers were interested not only in ranking alternatives but also in establishing the superiority of an alternative over others. There are varieties of attributes which may either support or oppose a particular alternative. By employing a single attribute analysis, as presented in Table III, it is evident that each given attribute produced significantly different preference choices. For example, if one chooses to maximize TCU (tire cushioning) of the automobile the first three preferences are tire T02, T09 and T13. Whereas to minimize tire noise pollution (TNP) the first three preferences are T02, T10 and T06. So it is observed that a multiple criteria analysis approach is more suitable than a single criterion analysis. When considering multiple criteria and attributes, the presented approach used ten attributes to assess alternative tires.

Similarly, using expert opinion and pairwise comparison of attributes, weighted normalized weights for each attributes obtained. Further considering multiple attributes, their corresponding weights and objective function; thirteen alternative tires evaluated. From Table V it is clear that alternative tire T02 is the first, and T01 is the last preferred choice, if AHP weights are assigned to each attributes. In case,

persons involved in decision-making are of the opinion that equal or unequal random weights given to all tire attributes, it is evident that the present model exhibits sensitively. The sensitivity analysis shows variation in the ranking of alternative tires (Table V). After the sensitivity analysis, tire T02 with load carrying capacity of 1090 kg, having very good tire cushioning while driving, having 2.5 years of life, the best thread depth, and very excellent tire grip in dry weather is the ideal first preference choice. In case, if the inclination towards an ideal preference is not satisfactory, then this approach is quite helpful to an analyst who is interested not only in ranking alternatives but also in establishing the superiority of an alternative over others.

VI. CONCLUSION

The paper presents a multi criteria approach for practical decision-making. Here the approach evaluates the decision hierarchy and derives weights for multiple criteria and their attributes. The approach also incorporates these weights and does multi criteria decision analysis. The model synthesizes the preference relationships for each alternative tire to produce the desired outranking relationship between the entire alternatives. The evaluation criteria for alternative tires were broadly related to tire sustainability, tire road performance, environmental issues, and tire purchase cost and tire road grip. In the presented model, limiting factor is five criteria and ten attributes, to assess the thirteen tires. Considering the expected growth of automobile manufacturing sector, in future, one could extend the present work with other criteria and attributes, and also he/she incorporates the fuzzy characteristics. In the auto industry, the approach is quite helpful to any decision maker who is interested not only in ranking alternatives but also in establishing the superiority of an alternative over others if it exists.

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