Project Report:

Decision Model for a Sedan Car

Course Title: Decision Making

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Abstract

There are a large variety of sedan cars available in the market today in the US. Therefore deciding on what sedan car suits you best is difficult. This study created a hierarchical decision model to determine the best characteristics of a sedan car. This model has been chosen because it allows users to easily visualize how each criterion at each tier impacts the decision. It is also applicable for manufacturers to realize what characteristics need to be improved.

This paper will look at the following six criteria: fuel economy, overall crash test rating, costs, features, performance, and dependability. Although there are other factors that go into a sedan car, we felt these six are the most important criteria for selecting a sedan car. The authors of this document are considered experts for evaluating sedan cars using the pairwise comparison. The use of the HDM along with pairwise comparison allowed for the creation quantified weighted values for each element at each tier. Using the HDM and inputting the top five best-selling sedans of 2012 resulted in the Honda Accord LX 2012.

Introduction

The sedan is one of the most popular vehicle body designs on the market today. A sedan, by definition, a car with two full rows of seats and four doors. Sedans are roomy and comfortable cars with plenty of room to fit up to five people [1]. There are a variety of car manufacturers such as Honda, Toyota, Ford and BMW. Every manufacturer possesses a line of sedan style cars with different trims and options available to meet your needs and driving style. This study is going to apply the Hierarchical Decision Model (HDM) to help with the selection of the most desirable sedan characteristics. The HDM purpose is to aggregate opinions of experts and gets rankings of each characteristic. The pairwise comparison method will be used to determine the weight of each sedan characteristic. The goal is to quantify any desirable sedan car, realistic or theoretical.

Methodology

Assumptions

The selection criteria are determined based on the following key assumptions to help simplify and make the HDM more robust:

1. Self-style experts; the subjective values are based on the team members' desirability.
2. Engine size is not considered.
3. Engine type is not considered i.e. hybrid, combustion, and electric.
4. Brand is not considered.
5. Features of a car are all weighted equally. Refer to Table 1.

Selection Criteria

The ideal sedan will be evaluated on six main criteria; fuel economy, overall crash test rating, manufacturer's suggested retail price (MSRP), annual maintenance cost, features performance, and dependability. Each sedan criterion was subjectively chosen based on our research and expertise. Each criterion contains unique alternatives based on the desirability function. The

alternatives for each criterion encompass the upper and lower limits that may apply to any available or theoretical sedan vehicles.

Fuel economy is how many miles a car can travel per gallon of gasoline. It is important to the buyer who desires to save money. A vehicle that gets 30 miles per gallon (MPG) will cost $938 less to fuel each year than one that gets 20 MPG. This is assuming 15,000 miles of driving annually and fuel cost of $3.75. The fuel economy alternatives consist of 0 to 15 MPG, 16 to 24 MPG, 25 to 30 MPG, 31 to 36 MPG, 37 to 45 MPG, 46 to 59 MPG and 60 MPG and up.

Overall crash test rating is how well the vehicle will protect the driver and other occupants in case of a collision. It is important because in an accident or collision, a higher safety rating will protect the driver and passenger the greatest. It could be the difference between life and death. The overall crash test rating contains the following alternatives: 0, 1, 2, 3, 4, and 5 Star.

Cost of the vehicle is based on two sub-criterions, manufacturer's suggested retail price and maintenance and repair cost. MSRP is the purchase price of the sedan vehicle. It does not take into consideration if the buyer chooses to negotiate the price down or fees that may be applied for example license and registration fee or insurance premiums. Maintenance and repair cost is how much the owner will have to pay to maintain the vehicle for five years. Both are important to the buyer who wants to save money. MSRP comprises of the following alternatives: 0 to $14,999, $15K to $17,999, $18K to 22,999, $23K to 28,999, $29K to $35,999, $36K to $49,999, $50K to $74,999, and $75 and up. 5 year maintenance and repair cost alternatives are 0 to $1,499, $1,500 to $2,499, $2,500 to $3,499, $3,500 to $4,999, $4,500 to $6,499, $6,500 to $8,499, and $8,500 and up.

Features of a car deliver conveniences and safety aids to the driver. This criterion is divided into two sub-criterions: interior and exterior features. A list of five interior and exterior features was subjectively chosen from our researched and expertise, refer to Table1. Each sub-criterion

contains five alternatives: Fulfill 0, Fulfill 1, Fulfill 2, Fulfill 3, Fulfill 4 and Fulfill 5 of the features on the list. This assumes each feature are weighted the same value.

Table1. List of Exterior and Interior Features

Exterior Features	Interior Features
Moon roof	6+ Speaker System
4 Wheel disc brakes	Push Button Start
Fog Lights	Leather Seats
High Intensity Discharge (HID) Lights	Navigation System
Heated Mirrors	Automatic Climate Control

For example, if a sedan car matches three of the exterior features it will received the alternative Fulfill 3. Another example, if a sedan car matches none of the features on the list it will receive the alternative Fulfill 0.

Performance is based on an Automotive Performance, Execution and Layout (APEAL) study. The performance component is based on owner satisfaction with the vehicle's powertrain and suspension system such as acceleration, handling stability, braking performance and shift quality [2]. This study is based on a one to five point scale

Dependability is based on a Vehicle Dependability Study (VDS). The study surveys owner-reported problems for the first 3 years of ownership. The measurement is based on a five point scale based on problems that have caused a complete breakdown or malfunction of any component, feature, or item [3].

Methodology

The methods used to determine the best characteristics of a sedan car are the HDM and pairwise comparison method created by Dr. Kocauglu [4]. The hierarchical decision model is a decision system that relates each criterion based on weighted values to the final decision [4]. Figure 1 illustrates the HDM with no weighted values. In this model each element was compared to the rest of elements at the same level of tier by distributing a total of 100 points between the two elements [4]. For example, when comparing fuel economy to performance; fuel economy may get 25 resulting in performance receiving 75. In this example, performance is

three times more desirable to the decision maker than fuel economy. In order to reduce the inconsistency among the experts as much as possible, we asked the experts to take a "desirability" approach rather than "realistic" on the comparisons. The definition of a desirability approach is one that chooses the most preferred alternative rather than what already exists today. By enabling this approach to each expert, the expected inconsistency rate is projected to be under the acceptable value of less than 0.1 [4].

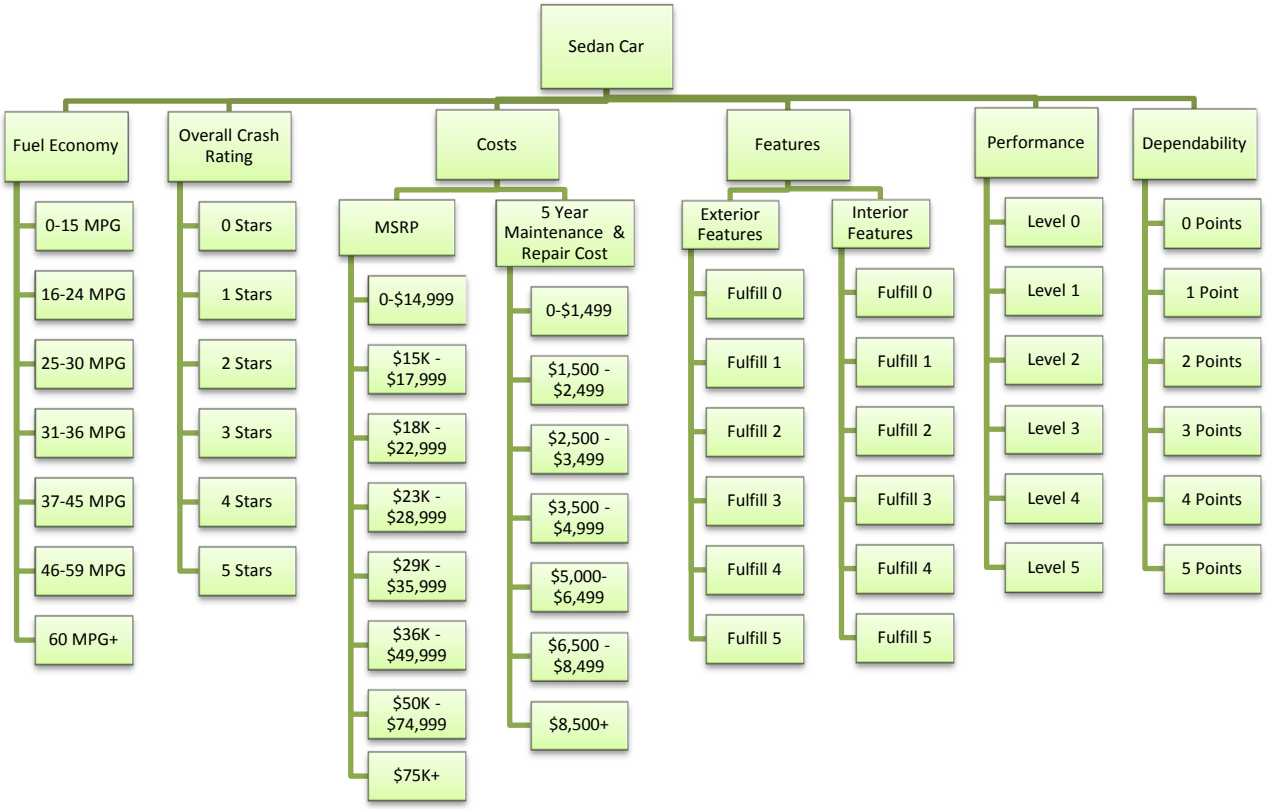

Figure1. Hierarchical Decision Model

The elements being compared are the following: Fuel economy, overall crash rating, cost, features, performance, dependability, and their associated alternatives. The first step is to create matrices that display the relative values between each element at the same tier. A total of three matrices are needed. Matrix A displays the distribution of 100 points for one element versus the other element in a tier. For simplicity, let FE = Fuel Economy, OCR = Overall Crash Rating, C = Cost, F = Features, P = Performance, and D = Dependability. See below for Matrix A at Table2:

Table2. Matrix A- Distribution of points

Matrix A	FE	OCR	C	F	P	D
FE	X	25	65	40	45	30
OCR	75	X	75	70	65	70
C	35	25	X	40	45	30
F	60	30	60	X	45	30
P	55	35	55	55	X	40
D	70	30	70	70	60	X

The next step is matrix B, this matrix is created to show how each element is related to each other by dividing each element's point by its reciprocal. For example, the value in [FE: OCR] (column: row) is divided by the value in [OCR: FE]. See below at Table3 for computed Matrix B.

Table3. Matrix B- Relationship

Matrix B	FE	OCR	C	F	P	D
FE	1.00	0.33	1.86	0.67	0.82	0.43
OCR	3.00	1.00	3.00	2.33	1.86	2
C	0.54	0.33	1.00	0.67	0.82	0.43
F	1.50	0.43	1.50	1	1	0
P	1.22	0.54	1.22	1.22	1.00	0.67
D	2	0	2.33	2	2	1

The next step is to create the last matrix, Matrix C, by dividing the values in one column by the values in the adjacent column. For example, values in column "OCR" will be divided by values of column "C." The purpose of this matrix is to show how consistent an expert is in his/her weights for each pair of elements. The variance of this matrix implies the consistency of judgments. If variance is low then it can be concluded that the expert is consistent. The computed Matrix C is shown in Table4.

Table4. Matrix C-consistency

Matrix C	FE/OCR	OCR/C	C/F	F/D	P/D
FE	3.00	0.18	2.79	0.81	1.91
OCR	3.00	0.33	1.29	1.26	0.80
C	1.62	0.33	1.50	0.81	1.91
F	3.50	0.29	1.50	1	2
P	2.27	0.44	1.00	1.22	1.50
D	5	0	1.00	2	2
Mean	**3.14**	**0.29**	**1.51**	**1.15**	**1.59**

After the creation of Matrix C, the values were normalized as D = 0.10, P = 0.08, F = 0.06, C = 0.24, OCR = 0.30, and FE = 0.22. This study employed HDM software package developed by Dr. Kocaoglu to perform the pairwise comparison calculations for each expert's judgments at each tier.

HDM with Weighted Values

Once the team entered in their judgments through use of the HDM software package, the final HDM with relative weights was created (see Figure2). At the first level of the HDM, it can be seen that cost (0.22) has the largest influence followed by fuel economy (0.19), performance (0.17), dependability (0.17), overall crash rating (0.13) and features (0.12).

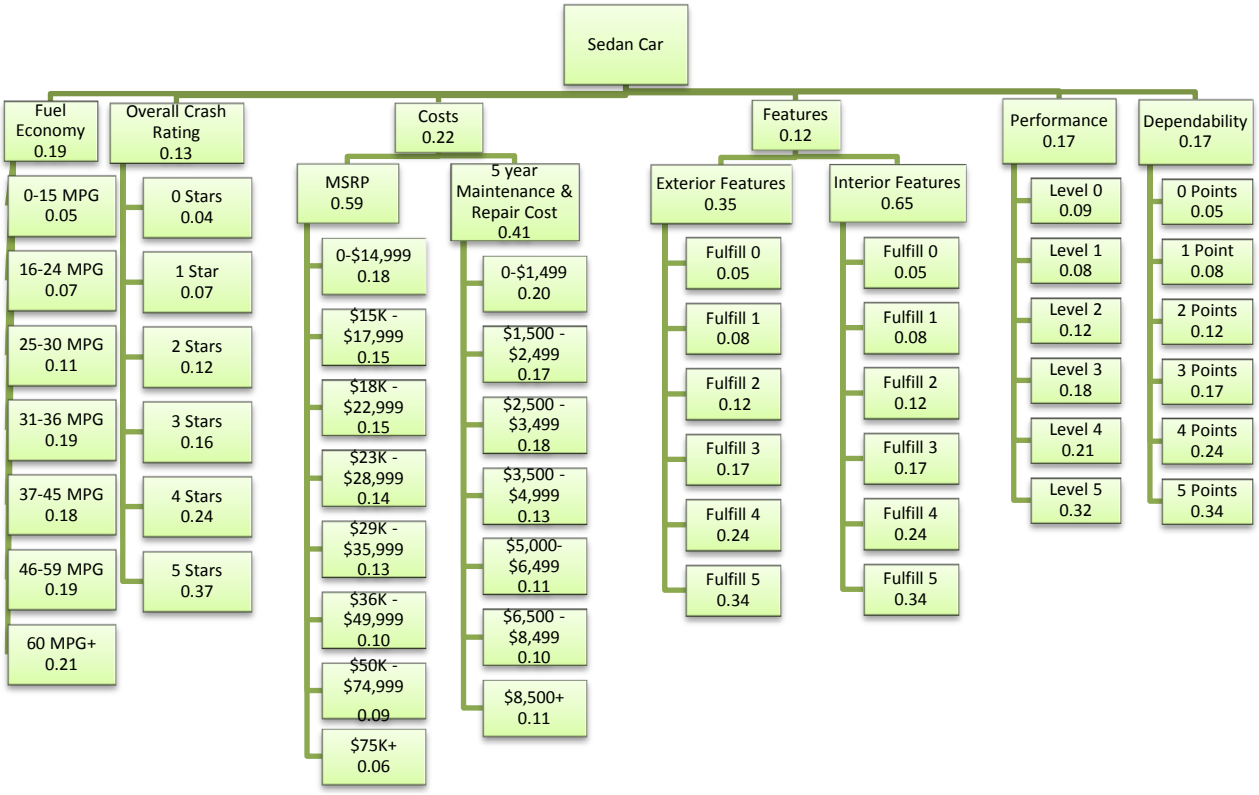

Figure2. HDM with Relative Weights

Results

Inconsistency and Agreement Level

As it can be seen in Table5, the rate of inconsistency for each expert is less than 10%. So we are confident to say that each expert was consistent. See appendix B Table9 for more details.

Table5. Inconsistency of Each Expert

Experts	Inconsistency
Bahar	0.02
Patrick	0
Larry	0.01
Harry	0
Yen	0

Table6 provides the information for agreement/disagreement between experts. ANOVA table (Table6) has been created for sedan car decision model through HDM software package developed by Dr. Kocaoglu. Here, it is assumed H_0 as there is disbarment between team members. To accept or reject the H_0 this study referred to Table6 for F-test values. The F-test value for this model is 3.54 which greater than all critical F-value. So it can be concluded that there is not statistically significant disagreement between experts and H_0 is rejected.

Table6. ANOVA Table for Sedan Vehicle HDM

Source of Variation	Sum of Square	Degree of freedom	Mean Square	F-test Value
Between Subjects:	0.05	51	0.001	**3.54**
Between Candidates:	0	4	0.000	
Residual:	0.05	204	0.000	
Total	0.1	259		
Critical F-value with degree of freedom 51 & 204 at 0.01 level:				1.62
Critical F-value with degree of freedom 51 & 204 at 0.025 level:				1.51
Critical F-value with degree of freedom 51 & 204 at 0.05 level:				1.41
Critical F-value with degree of freedom 51 & 204 at 0.1 level:				1.31

Calculating Scores for an Ideal and Top 5 Bestselling Sedans

In order to calculate the score for each element, the relative weights in Figure2 were used. Here, the relative weight of each element has been multiplied by the relative weight of its associated upper level element. For example the score for fulfill 2 under the exterior design has been yielded by multiplying the relative weight for fulfill 2, exterior features, and features which is 0.12* 0.35* 0.12 = 0.005. All the scores are located in appendix A Figure5.

Referring to Figure5, the characteristics of an ideal sedan is determined by choosing the highest alternative's score from each criterion. Table7 illustrates the characteristics and the score for the ideal sedan.

Table7. Characteristics of an Ideal Sedan

Ideal car	**Characteristics**	**Score**
Fuel Economy	60 MPG +	0.0399
Overall Crash Rating	5 stars	0.0481
MSRP	0 – $14,999	0.0234
5 Yrs Maintenance& Repair Costs	0 – $1,499	0.018
Exterior Features	Fulfill 5 features	0.0143
Interior Features	Fulfill 5 features	0.0265
Performance	Level 5	0.0544
Dependability	5 points	0.0578
Total Score		**0.2824**

In order to test the model, this study scores the top 5 bestselling sedan car in 2012 [5]. The results showed that Honda Accord LX is the best sedan car. See Table8.

Table8. Scores of Top 5 Bestselling sedan 2012

Bestselling sedan 2012	No1. Toyota Camry LE		No2. Honda Accord LX		No3. Honda Civic LX		No4. Nissan Altima 2.5		No5. Toyota Corolla LE	
	Char.	**Score**	**Char.**	**Score**	**Char.**	**Score**	**Char.**	**Score**	**Char.**	**Score**
Fuel economy (MPG)	30	0.0209	31	0.0361	32	0.0361	32	0.0361	30	0.0209
Overall Crash Rating (*)	5	0.0481	5	0.0481	4	0.0312	5	0.0481	4	0.0312
MSRP ($)	22,680	0.0195	21,680	0.0195	18,165	0.0195	21,760	0.0195	18,180	0.0195
5 Yrs Maint. & Rep. Costs ($)	2,232	0.0153	1,850	0.0153	1,882	0.0153	2,191	0.0153	2,111	0.0153
Ext. Fet. (# fulfill)	1	0.0034	1	0.005	1	0.0034	1	0.0034	0	0.0021
Int. Fet. (# fulfill)	2	0.0094	2	0.0062	0	0.0039	0	0.0039	1	0.0062
Performance(level)	3	0.0306	3	0.0306	3	0.0306	3	0.0306	2	0.0204
Dependability(point)	4	0.0408	3	0.0289	3	0.0289	2	0.0204	**4**	0.0408
Total score	**0.188**		**0.1897**		**0.1689**		**0.1773**		**0.1564**	
Rank	**2**		**1**		**4**		**3**		**5**	

Discussion

Before we discuss the result of this study, first we want to point out the challenge we faced. In this study, we had difficulty when on the features criterion. We initially planned to have three alternatives for the interior and exterior feature sub-criterion. The alternatives were low, medium and high level of features. It was difficult for us to define and differentiate the three different levels of features. For example low level exterior features would include steel wheel rims and front only disc brakes and medium exterior features would include four wheel disc brakes, 17+ inch alloy rims and high-intensity-discharge headlights. The issue we encountered was if a sedan possesses features from both levels, for example front wheel disc brakes with 17 inch alloy rims, how would you define which alternative it falls in of the exterior feature level? Low or Medium? To solve the problem, as explained in “Selection Criteria” section, a list of interior and exterior features was defined and the alternatives were measured by the number of fulfillments.

Then let us review and discuss the outputs of our study. This study created HDM to score the top 5 bestselling sedans in 2012. Figure3 visualizes the comparison between the ideal sedan car and the top 5 bestselling sedan in 2012. In this figure, when looking legend area, “R” is car’s rank in our model and “M” means market ranks. For example, R2 and M1 in the legend for Toyota Camry LE is inferred as Toyota Camry LE ranked 2 in the HDM model while it ranked as the first best-selling sedan in the market.

However, in the market, Toyota Camry LE beat Honda Accord LX while according to the HDM Honda Accord LX ranked first and Toyota Camry LE scored second. Further look into the scoring, the difference was due to a higher score on fuel efficiency for the Honda Accord LX that allowed for it to score higher overall. Based on the Figure3 all manufacturers have a close fuel efficiency score to the ideal sedan except Toyota. Another observation from the scoring of the model showed that Toyota Corolla LE received the lowest rank in both market and HDM. This study suggests that Toyota needs to improve fuel efficiency for Camry LX and Corolla LE in order to get closer to the ideal sedan.

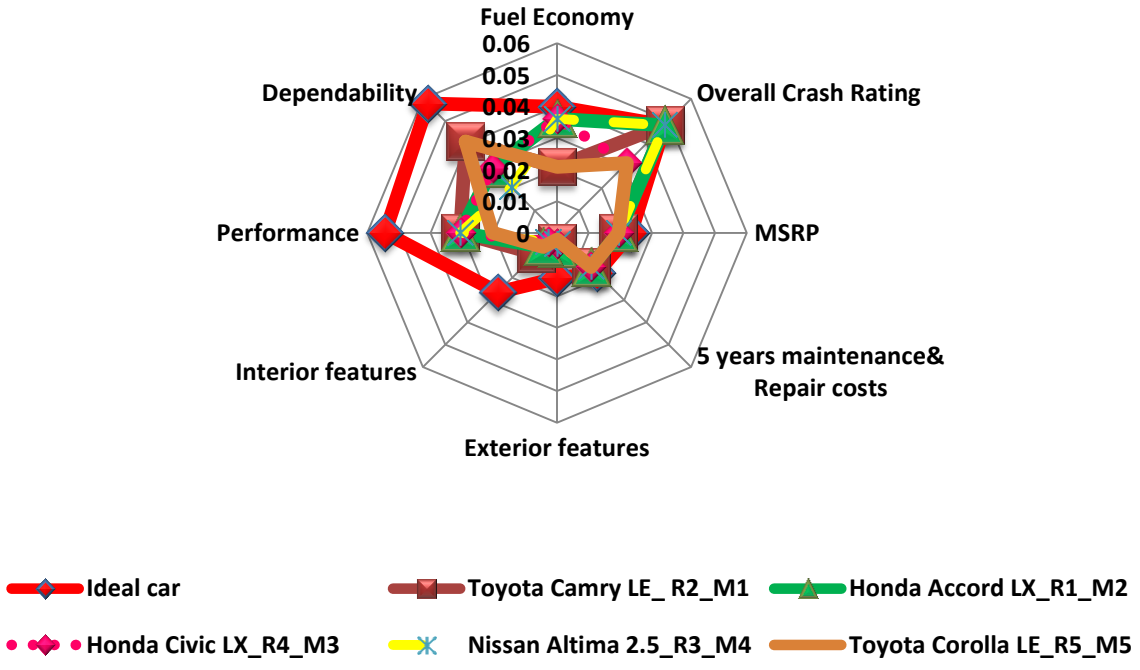

Figure3. Ideal Sedan vs. 5 Bestselling Sedan in 2012

In addition, from Figure3 it can be concluded all sedans meet the desirability for MSRP and 5 year maintenance and repair cost criteria. But hardly any top 5 bestselling sedan reached to the desirable dependability, performance, and interior features.

Conclusion

In conclusion, we were able to utilize the hierarchical decision model in conjunction with the pairwise comparison method to create a model to choosing a sedan car. Any sedan car may utilize this model, just note that the weights are based on the team's desirability. The most desirable sedan car characteristics and its relative weights are provided on Table7. To examine the model, the top 5 bestselling cars in 2012 were entered into the model. The top 5 cars and their relative weights are show on Table8. The bestselling car in 2012 was the Toyota Camry LE and the runner up with the Honda Accord LX. According to the model, Honda Accord LX scored the highest followed by the Toyota Camry LE. This is due to the fact that the fuel efficiency is heavily weighted and the Honda Accord LX is capable of more miles per gallon.

Further Research

The further study is to develop the model based on the subjective values from the larger numbers of experts. Which helps the model to reflect broader judgments and consequently it will be applicable for the bigger demographics.

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Appendix A

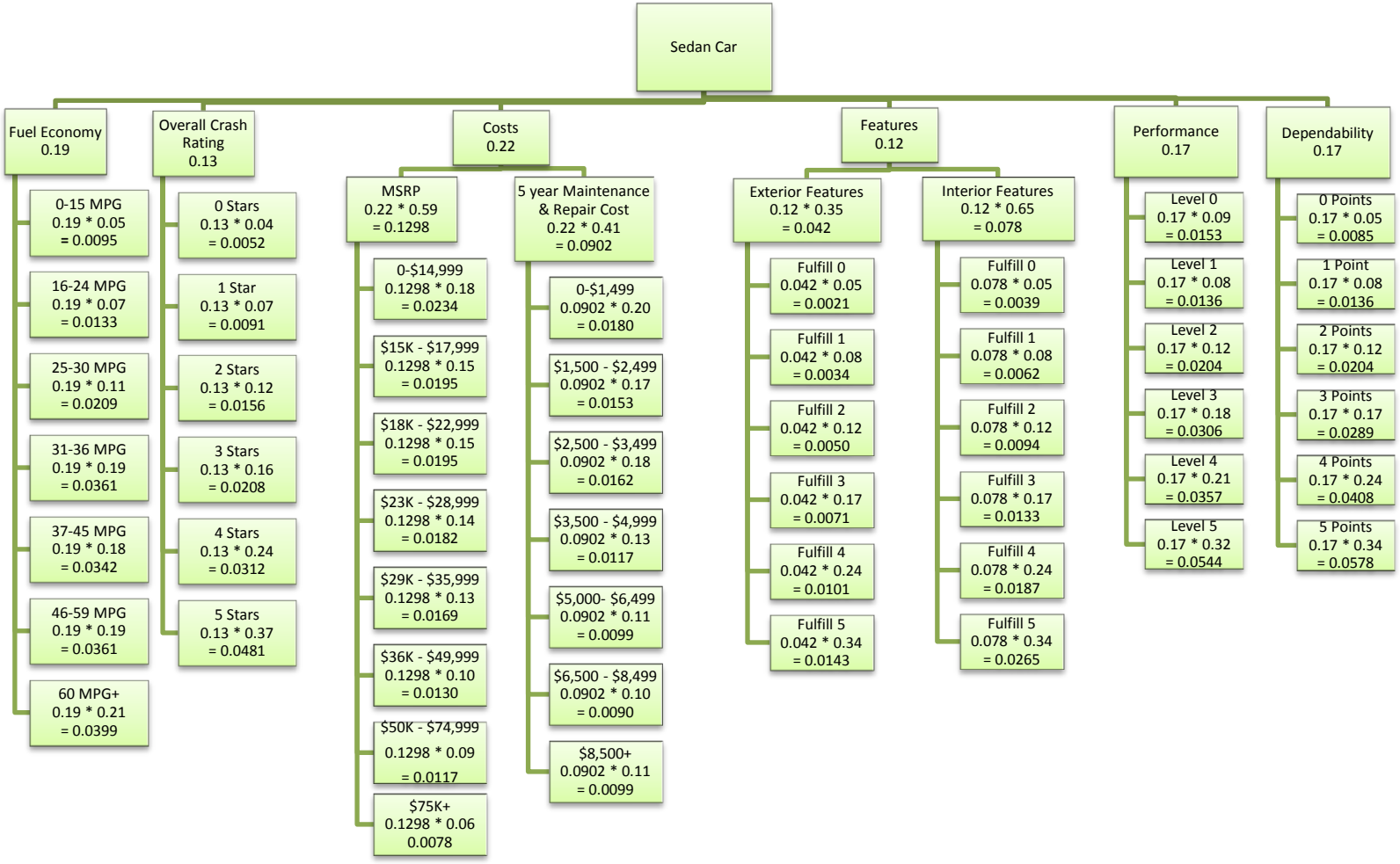

Figure5. Element's Score in the HDM

Appendix B

Table9. Consistency for All Experts

	Main components (level 1)	Fuel Economy	Overall Crash Rating	Cost	Features	Performance	Dependability	MSRP	5 Years Maintenance Costs	Exterior Features	Interior Features
Bahar	0.05	0.05	0.06	0	0	0.07	0.06	0.08	0.26	0.07	0.07
Patrick	0	0.04	0.01	0	0	0	0	0.02	0.03	0	0
Larry	0.01	0.01	0	0	0	0	0	0.01	0.01	0	0
Harry	0.01	0	0	0	0	0.25	0	0.03	0.01	0	0.03
Yen	0.02	0.02	0.01	0	0	0	0.01	0.01	0.02	0	0