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SECOND HAND CAR PURCHASING PROBLEM VIA AN INTEGRATED MULTI-CRITERIA DECISION MAKING SOFTWARE

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Abstract

Automotive industry shows a growing trend in recent years. Both new car and used car market is one of the leading sectors in many countries. In recent years, people prefer to purchase used or second-hand cars rather than new cars. Therefore, it is important to make right decision while purchasing second hand car. Consequently, second hand car purchasing problem (SHCPP) is an up-to-date multi criteria decision problem (MCDMP) almost throughout the world. A software is developed by using C# programming language and this software is usedto solve SHCPP problem. By using Entropy or Fuzzy Analytic Hierarchy Process (FAHP) methods weights of criteria of MCDM problems are calculated by using the developed software. Later this software

can be used to determine the optimum alternative using Multi-Attribute Utility Theory (MAUT) or Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) which can be selected by user. Software has the flexibility to solve many different problems and has the diversity to select both methods of calculating weights of criteria and solution methods by user.

Keywords

FAHP, TOPSIS, MAUT, Entropy, Multi Criteria Decision Making

1. Introduction

The automotive industry is one of the most important income source of the country's economy.Automotive industry has a large share in sales of the durable products. Cars have approximately %70 of the industry, which has all of the motor vehicle production (Onat, 2007). 87% of all vehicles produced in Europe in 2015, is composed of cars (Web – Acea, 2016a). Also, 91.5 million motor vehicles were produced globally in 2015 and 73.5 million of this production were cars (Web – Acea, 2016b). Based on this information, it is clear that, automobile industry is a leading industry all over the world.

Second hand car sales has increased considerably compared to the new car sales in recent years. People may prefer second hand cars because of many different reasons. Numerous different criteria is take in consideration while purchasing second hand cars and the importance of the criteria may vary from person to person. The differences in the price of second hand cars is certainly the most important factor in the market for second hand cars (Asilkan & Irmak, 2009). Criteria that are influence on second hand car purchase are following; price, first registration, kilometer, fuel type, gear type, damage, engine size, engine power, color etc. The second hand car purchasing is becoming a common decision making problem because of the criteria vary from person to person and second hand car sales are increasing drastically. In this sector, where is a high circulation, it is important for the people to choose the most suitable car for them as soon as possible. Hence, it would be useful to prepare systems that can solve this problem as soon as possible and help decision makers in this regard.

The degree of influence of decision-making is usually related to the decision makers' decision to analyze the interrelation of criteria (Uygun, Demir, & Erkan, 2016). Many different methods have been developed for years to solve MCDMPs such as Analytic Hierarchy Process

(AHP), Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), Analytic Network Process (ANP) and VIKOR etc. From the simplest to the most complicated decisions in many different areas such as manufacturing, health care, tourism, economy and IT can be incorporated into the MCDMP pool. MCDMPs, structural involve various criteria and / or sub-criteria. Decision makers try to choose the optimum alternative from the existing alternatives by taking into consideration all criteria and sub criteria. Hence, the accuracy of the decision and the speed of decision making is important in many problems.

By using C# programming language a software is developed for MCDM problems. The software is designed to be user friendly and presented an opportunity to choose different solution and analysis methods for decision makers. Entropy and FAHP methods are used forweighting of criteria. Later MAUT and TOPSIS methods whichcan be selected by users are used for choosing the best alternative. This software which is prepared for the SHCPP, has also the ability to solve different problems.

2. Second Hand Car Sector

It is seen that automobile sector is leading sector for the countries with advanced industry. Automobile sector which holds about 80% of motor vehicle production in worldwide, is a sector that consider the customers' demands and expectations. Developments in the automobile industry is closely watched around the world.

On the other hand, people's car purchasing preferences are more second hand cars nowadays. Second hand car sales are more than new car sales in many countries(Asilkan & Irmak, 2009). Second hand car sector is already showing a significant increase. Second hand car market has exceeded two times the new car market volume in the US(Lee, 2006). This situation is not much different in Europe. By year of 2006, second hand car market corresponds to approximately 30% in Germany, 23% in England and 20% in France (Asilkan & Irmak, 2009). These rates are estimated to be 40% in present.

Nowadays, especially with the help of the internet which is exceptionally widely used, second hand car commerce has started to be more frequent. It is clear that second hand cars that are more in demand than new car almost everywhere in the world retain their fascination. Car manufacturers are obliged to sell their own brand second hand cars on their own website because of sales figures of second hand cars on the internet.

3. Related Works

3.1Fuzzy Analytical Hierarchy Process (FAHP)

AHP is one of the multi criteria decision making methods which defined by (Thomas L Saaty, 1980) in 1980. AHP is a decision making method that solves a complex MCDMP into a hierarchy (Montazar, Gheidari, & Snyder, 2013). Because of the advantages of the AHP such as flexibility and ease of use, its usage will continue to increase (Ho, 2008). However, there is no uncertainty in AHP. AHP will not ensure a solution if there is uncertainty in data of problem (Padma & Balasubramanie, 2011). FAHP developed to fill the deficiency of AHP caused by the weakness to solution under uncertainty. FAHP represent fixed value judgements to interval judgements that is more confident. So, FAHP is an influential method to solve uncertainty problems that are more closely real life problems.

There are many studies about FAHP in the literature. Studies particularly made in recent years on FAHP that has been the subject of thousands of studies since many years are listed below:

Table 1: *Studies Made in Recent Years on FAHP*

Author(s)	**Explanation**	**Year**
Wang et al.	Using FAHP method in safety evaluation of coal mine and an application in China.	2016
Ruiz-Padillo et al.	A methodology is developed to sort road stretches included in a Noise Action Plan. They use two different FAHP methods.	2016
Leong et al.	A multi objective linear programming modelis developed to synthesize inter-plant chilled and cooling water network.	2016
Babashamsi et al.	Determining the prioritization of pavement maintenance alternatives using integrated FAHP&VIKOR method.	2016
Biju et al.	Using FAHP method for evaluation of customer requirements and sustainability requirements in an umbrella manufacturing industry.	2015
Nguyen et al.	Using FAHP method to evaluate and measure complexity in transportation projects.	2015
Gim & Kim	Five hydrogen storage systems for automobiles are evaluated using FAHP method in respect to eight criteria.	2014
Tasri & Susilawati	Developing a methodology using FAHP method to determine the most appropriate renewable energy sources in Indonesia.	2014
Montazar et al.	Evaluation of performance of different irrigation projects using FAHP method.	2013

Yilmaz	Selection the supplier of an oven manufacturer using FAHP-VIKOR method.	2012
Sofyalıoglu & Kartal	Using FAHP method while determiningsupply chain risks,	2012
Tang & Chang	An application based on goal programming and FAHP to solve capital budgeting problem in a car rental company.	2012
Padma & Balasubramanie	Using a FAHP model while evaluating occupational menace the spawning of shoulder and neck pain.	2011
Karimi et al.	Using AHP and FAHP methods while selecting the best wastewater treatment process and ranking of these processes.	2011
Tiryaki & Ahlatcioglu	Portfolio selection using FAHP method.	2009
Ozgormus et al.	Selection of personnel via 7 different criteria using FAHP in a company.	2005

It is clearly that FAHP is a current issue and it will continue to be the subject of many studies in the future. Implementation performed in this study has benefited from steps of Chang's extended analysis.

3.2 Entropy Weight Method

Entropy is a method that is to determine the weights of criteria and widely used in MCDMPs. If we look at works on Entropy, we can see numerous works. Some of these works are following: (Shemshadi, Shirazi, Toreihi, & Tarokh, 2011) studied Entropy method with Fuzzy VIKOR method to supplier selection. (Percin & Cakir, 2013) studied Entropy to sorting of R&D performance of the EU countries. (Mon, 1995)studied on performance measurement of weapon systems. (X. Li et al., 2011) studied Entropy with TOPSIS on evaluation of the safety of coal mines. (Zou, Yun, & Sun, 2006) studied on measurement the quality of the water sources. (Yari & Chaji, 2012) studied Entropy method to select operator. (Abidin, Rusli, & Shariff, 2016) designed an internal security system based on an integrated Entropy-TOPSIS method.(L. Li, Liu, & Li, 2014)proposed a customer satisfaction method using Entropy and AHP methods.

3.3 Multi Attribute Utility Theories - MAUT

MAUT is a method to find the most beneficial alternative based on both qualitative and quantitative criteria. If we look at works on MAUT, (Gómez-Limón, Arriaza, & Riesgo, 2003)studied on risk aversion coefficients. They present a method based on MAUT to acquire risk aversion. (Ananda & Herath, 2005)determined social risk preferences in forest using MAUT. (M. R. Yilmaz, 1978)dedicated a survey to the axiomatic progressions in MAUT. (Canbolat, Chelst, & Garg, 2007) presented a combine method to select optimal country which to

locate a manufacturing plant. They combined a decision tree and MAUT method. They used the outputs of decision tree as input to MAUT. (Loetscher & Keller, 2002) presented a decision support system called SANEX to select the most useful sanitation system alternative. They have used MAUT to compare alternatives.

In this study, MAUT method is applied in two steps:

1. Normalizing the decision matrix of the following equation (1),

$$u_i(x_i) = \frac{x - x_i^-}{x_i^+ - x_i^-} (1)$$

2. Calculating benefits obtained by multiplying the normalized decision matrix by weight of the following equation (2):

$$U(x) = \sum_{i=1}^{n} (u_i(x_i) * w_i) (2)$$

3.4 Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)

TOPSIS method was developed by (Hwang & Yoon, 1981)in 1981. TOPSIS is a MCDM method by determining the alternative with the shortest distance from positive ideal solution and the longest distance from negative alternative solution (Kazan, Karaman, Akcali, & Sismanoglu, 2015). There are many studies in which TOPSIS method was used in the literature. (Lima Junior, Osiro, & Carpinetti, 2014)studied supplier selection problem by comparing the FAHP and fuzzy TOPSIS method. (Sang, Liu, & Qin, 2015) studied staff selection problem by using fuzzy TOPSIS method. (Kazan et al., 2015) studied on a TOPSIS practice to find the difference of TEOG examination from other examinations. (Krohling & Pacheco, 2015)presented a new method based on TOPSIS compare of ranking algorithm performance.

In order to compare companies a TOPSIS model based on design of experiment is studied (Ic, 2014). For solving multi-level non-linear multi objective decision making problems of maximization type anew TOPSIS algorithms is proposed by (Baky, 2014). (Baykasoglu & Golcuk, 2015)developed a new model based on fuzzy TOPSIS and fuzzy cognitive maps. (Roshandel, Miri-Nargesi, & Hatami-Shirkouhi, 2013) studied supplier selection problem in detergent industry with fuzzy TOPSIS. In order to rank of renewable energy systems in Turkey a fuzzy TOPSIS method is developed by (Sengul, Eren, Eslamian Shiraz, Gezder, & Sengul, 2015).

(Ertugrul & Oztas, 2014) studied selection of the best and the most economical mobile line to meet business requirements with fuzzy TOPSIS method. (Vinodh, Prasanna, & Hari

Prakash, 2014)developed an integrated model based on FAHP-TOPSIS to determine the best plastic recycling method. (Guo & Zhao, 2015)studied optimal site selection for charging station of electrical vehicles by using fuzzy TOPSIS. (Senouci, Mushtaq, Hoceini, & Mellouk, n.d.) presented new TOPSIS approaches for selection of mobile network interface.

4. SHCPP via Integrated MCDM Software

Software which is prepared under the scope of this study has the flexibility to solve many different problems.It may have lots of criteria and alternatives that vary by the size of the problem. This software is capable of solving problems of different sizes. Also, calculating weights of the criteria and selection of the optimum alternative both can be made automatically via software. However, the selecting optimal alternative and the calculatingweights of the criteria can be determined with different methods selected by the user. Thus the software is a user oriented software. Users can select one of the Entropy or FAHP methods to calculate the weights of the criteria and can select one of the MAUT or TOPSIS methods to select the optimal alternative. Software was prepared using C# (sharp) language in M.S. Visual Studio 2013 .NET.

Second hand car problem have been studied in this study. It is considered that a user has decided to buy a brand and a model of the car. Thus, same brand and same model of the alternatives are assumedto be same in the practice. Alternatives are given from Sahibinden.com which is a popular second hand car website in Turkey. The name of alternatives are the advertisement numbers on the website. The optimum alternative will be chosen in these cars which have different properties via software. 12 different alternatives is evaluated under 6 criteria mentioned below:

- First Registration (FR) shows the date of the first registration of the vehicle to traffic.
- Mileage (KM) shows kilometers driven after first registration.
- Damage (DA) refers to the degree of damage of the vehicle.
- Fuel (FU) shows the type of fuel used in vehicle.
- Gear (GE) refers to the gear type of vehicle.
- Price (PR) shows the vehicle’s purchase price.

The hierarchical structure of SHCPP which has 6 criteria and 12 alternative described above is shown in Figure 1 below.

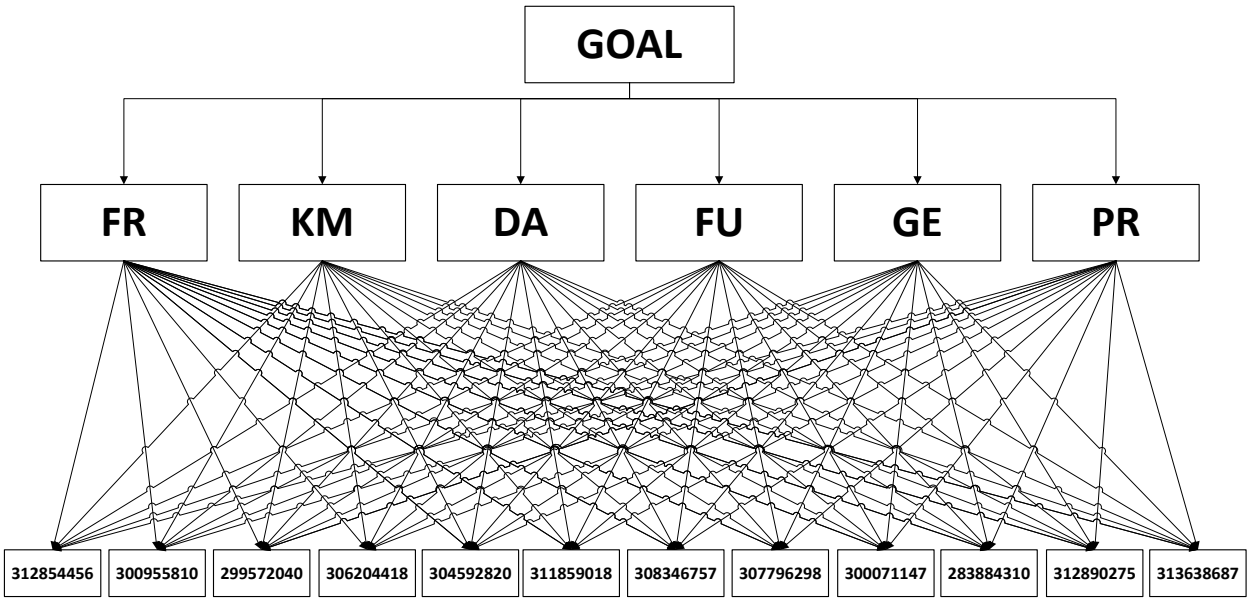

Figure 1: *The hierarchical structure of SHCPP*

Software which prepared in the study benefits from the initial matrices. Some of the criteria are used direct values and other criteria are used Saaty's 1-9 scale in the initial matrices(Thomas L Saaty, 1980). This situation is shown in Table 4.1:

Table 2: *Importance Scales of Criteria*

Criteria	Values
First Registration (FR)	2012,2013 etc.
Mileage (KM)	25000, 45000 etc.
Damage (DA)	Damage Free = 9 Less Damage = 7 Damage = 5 Very Damage = 3 Heavy Damage = 1
Fuel (FU)	Gasoline = 1 LPG = 3 Diesel = 5 Hybrid = 7
Gear (GE)	Manual = 1 Semi-automatic = 3 Automatic = 5
Price (PR)	50000 TL, 60000 TL etc.

Then, it is used fuzzy values of Chang's extent analysis to create fuzzy pair-wise comparison matrix (Chang, 1996). The corresponding values to qualitative expressions are shown in the Table 4.2 below:

Table 3: *Fuzzy Values to Qualitative Expressions*

Qualitative Expression	**Fuzzy Value**	**Opposing Value**
Equal	(1, 1, 2)	(0.5, 1, 1)
Moderately Preferred	(1, 2, 3)	(0.33, 0.5, 1)
Strongly Preferred	(2, 3, 4)	(0.25, 0.33, 0.5)
Very Strongly Preferred	(4, 5, 6)	(0.17, 0.2, 0.25)
Extremely Preferred	(5, 6, 7)	(0.14, 0.17, 0.2)

Users selects the method that they want (Entropy or FAHP) to determine the weights of the criteria through the screen. Software asks to the user to introduce the input file according to the selected method. After weighting process, users selects the method that they want (MAUT or TOPSIS) to choose the optimum alternative. Later the software can choose the optimum alternative in a reasonable time. This structure is shown in Figure 2 below:

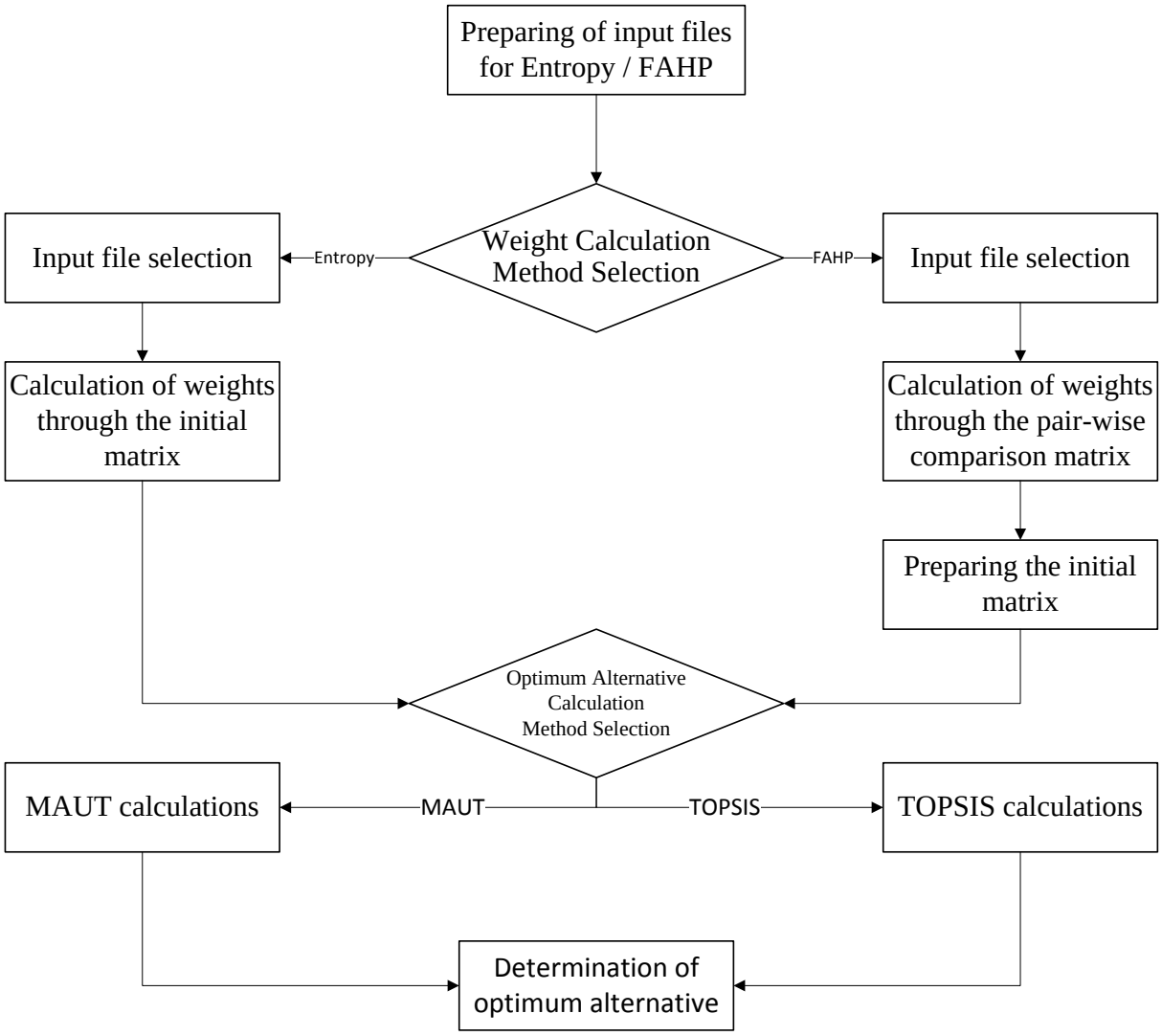

Figure 2: *Flow diagram of software*

The splash screen of the software is shown in Figure 3.

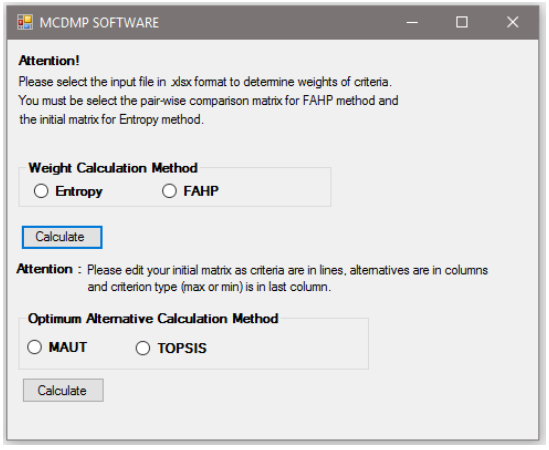

Figure 3: *The splash screen of the software*

Inputs need to be changed by the chosen method to run software because of different methods contain different requirements. Inputs will be used in SHCPP are prepared separately for each method. Software is run for all methods and results are evaluated. Sample images of inputs which are needed for Entropy and FAHP methods are shown in Figure 4 and 5 below:

307796298	300071147	283884310	312890275	313638687	CriteriaType
2012	2012	2014	2012	2012	max
25	20	33	21	22	min
7	5	3	1	7	max
7	5	7	7	5	max
3	5	5	3	3	max
52500	51500	51000	43500	52500	min

Figure 4: *Input file for Entropy method*

FR(l)	FR(m)	FR(u)	KM(l)	KM(m)	KM(u)	DA(l)	DA(m)	DA(u)
1	1	1	0,33	0,5	1	0,25	0,33	0,5
1	2	3	1	1	1	0,25	0,33	0,5
2	3	4	2	3	4	1	1	1
1	1	2	0,33	0,5	1	0,25	0,33	0,5
0,33	0,5	1	0,17	0,2	0,25	0,14	0,17	0,2
2	3	4	1	2	3	0,33	0,5	1

Figure 5: *Input file for FAHP method*

Software run by the help of prepared inputs and selects the optimum alternative in 4 different ways according to the combinations selected byusers .All of the combinations that users may select are shown in the following table.

Table 4: *Four Ways to Execute Program*

Weight Calculation Method	Optimum Alternative Calculation Method
Entropy	MAUT
FAHP	MAUT
Entropy	TOPSIS
FAHP	TOPSIS

Software is run accordingto the above table and the results obtained are shown in the following figures.

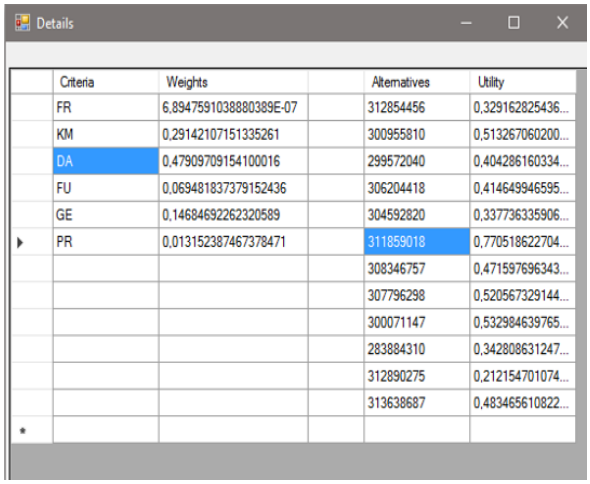

Figure 6: *Results of Entropy - MAUT*

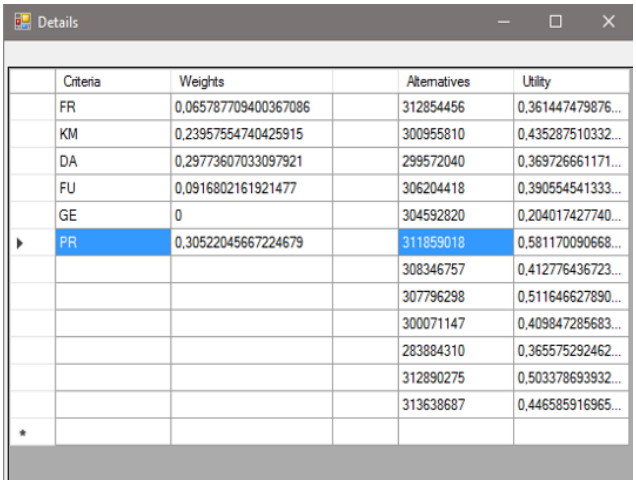

Figure 7: *Results of FAHP – MAUT*

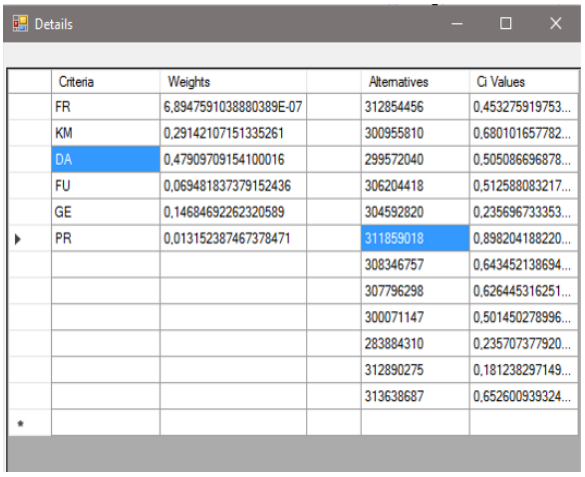

Figure 8: *Results of Entropy – TOPSIS*

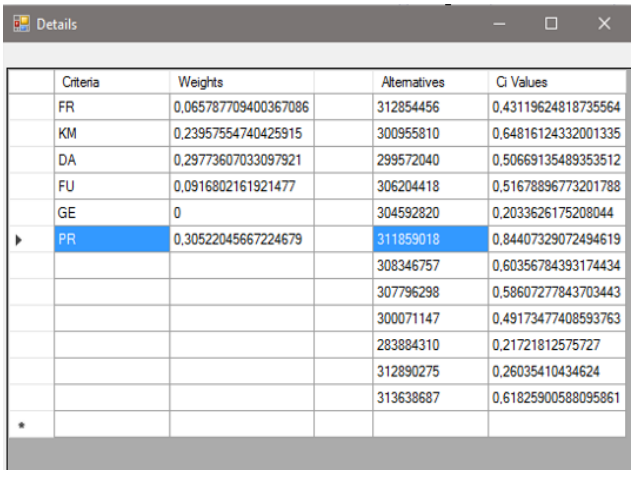

Figure 9: *Results of FAHP - TOPSIS*

5. Results

Results of the SHCPP are shown in Figures 6, 7, 8 and 9. Figure 6 shows the results that use Entropy method to calculate weight of criteria and MAUT method to determine the optimum alternative. Figure 7 shows the results that use FAHP method to calculate weight of criteria and MAUT method to determine the optimum alternative. Also, Figure 8 shows the results which use Entropy method to calculate weights of criteria and TOPSIS method to determine the optimum alternative. Figure 9 shows the results that use FAHP method to calculate weights of criteria and TOPSIS method to determine the optimum alternative. The optimum alternative are the same in 4 methods. However, the most significant and the least significant criterion is different according to different methods. Consequently, the advertisement number 311859018 car is the optimum car in all methods. The results are shown collectively in the Table 5.1.

Table 5: *All Results*

Method	Optimum Alternative	Most Significant Criterion	Least Significant Criterion
Entropy / MAUT	311859018	Damage	First Registration
FAHP / MAUT	311859018	Price	Gear Type
Entropy / TOPSIS	311859018	Damage	First Registration
FAHP / TOPSIS	311859018	Price	Gear Type

6. Conclusion

Today, second hand car sales are ahead of new car sales. Many people buy cars that fit their criteria online. People consider many different criteria to evaluate second-hand cars and try to choose the most suitable car for them. As a result, the second-hand car market has become a very large market and it is very difficult to select a car from this market. As a result of this difficulty, it is necessary to design a system that can help the decision makers to select the most suitable automobile in the shortest time and in the right way.

In this study, a software has been developed using C# programming language in M.S. Visual Studio 2013 .NET platform. It is intended to create a new look for the solution of MCDMP with the software. A structure that already exist about integration of FAHP, Entropy, MAUT and TOPSIS methods has been established. Meanwhile, a flexible model which has alternative methods depending on user selection has been presented. The presented software is also suitable for changingthe alternative and criteria numbers according to type of the problem. Within the scope of this study, the SHCPP is discussed as an example problem.

Problems of any magnitude can be solved with the desired method via the software developed. Numbers of criteria and alternatives can be changed as desired. In the future works, we will add new features and methods like Fuzzy ANP, VIKOR and Fuzzy Dematel etc. to the software and users will have more opportunities to choose different methods to solve different problems.

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