TODA:
Software for Multiple-Criteria Decisions

Cida Sanches, Administration Master's Program, FACCAMP, Araçariguama, Brazil

Samuel Ferreira Jr, SENAC University Center, Jundiai, Brazil

Givaldo Santos, UFScar: University Federal Sao Carlos, Campinas, Brazil

Marisa Regina Paixão, UNIP: University Paulista, São Paulo, Brazil

Manuel Meireles, Administration Master's Program, FACCAMP, Araçariguama, Brazil

ABSTRACT

This paper describes the use and application of the TODA (Trade-off Decision Analysis) method through a case study. The method uses the concept of trade-off applied to a prioritization matrix and, to define the weights, it takes the concept of causality into account. Studies have shown that the TODA achieves the same results as the competing AHP method. However, it is easier to operate. The methodology used is a case study concerning the choice of the type of car for a fleet of vehicles to be driven by salespeople. Together with the software application process, the methods that aided the weighting of the criteria are described and how the values of the alternatives are converted into coefficients of the objective function. The results clearly show that the method is easily applied, but the limitations of the case study method preclude forming generalizations.

KEYWORDS

AHP, Decision-Making Process, MCDM, Multiple-Criteria Decision-Making, Rational Decision, TODA, Trade-Off Decision Analysis, Trade-Off

INTRODUCTION

The decision-making process is recurrent in any organization, no matter its size or type. A decision is "a course of action chosen by the decision maker as the most effective available to achieve a goal or goals to solve a problem that worries him" (Jones, 1964, p. 23). Deciding is an action in the daily routine of companies of any size, to such an extent that authors such as Ansoff (1965) and Simon (1976) view it as the essence of managerial activities and, fundamentally, a decision-making process, which in turn is an eminently human activity.

The end of the decision-making process results in a decision that, according to Drucker (1967), is a systematic process of clearly defined elements that follow the following steps:

1. Classifying the problem;
2. Defining the problem;
3. Specifying the answer to the problem;

4. Deciding what is right rather than acceptable in order to meet the boundary conditions;
5. Building into the decision the action to carry it out; and
6. Testing the validity and effectiveness of the decision against the actual course of events.

The purpose of this paper is to describe the use and application of the TODA (Trade-off Decision Analysis) method by comparing it with the AHP method through a case study. According to Robbins and Coulter (2015, p.123), as the decision maker does not have all the information necessary for the decision, his rationality is bounded and the result is that "managers satisfy rather than maximize. That is, they accept decisions that are 'good enough'.

In the classical theory of management, linked to the positivist tradition of social science, rationality is defined as "the adequate choice from among alternatives and the suitable choice of a means of achieving set goals" (Oliveira, 1993, p.21). According to this concept, every decision should be made rationally, based on complete information on the company's goals, plausible alternatives, the probable results of these alternatives and the importance of these results to the organization (Cho, 2003).

According to Etzioni (1964), decision theory, which is fundamentally prescriptive, prescribes the steps to a rational decision. There has been growing interest in linking it to descriptive theories, which register and analyze how and under which conditions decisions are made. For a choice to be rational from an economic viewpoint, it is necessary for it to have the following characteristics:

1. Be complete, meaning that an individual must be capable of choosing from alternatives, e.g., should be able to say whether he prefers or A or B;
2. Be transitive, meaning that if an individual is capable of perceiving that he prefers A to B, and B to C, then he must prefer A to C: $(A > B > C \rightarrow A > C)$.

Decision-making can also be viewed as an effort to resolve the dilemma of conflicting objectives, which impedes the existence of the "optimum solution" and leads to a search for the "best solution that can be arranged" (Schmidt, 2003).

A decision may contain one, two, or more criteria for choosing. When there is only one criterion, the rational choice is to maximize the criterion variable (lowest price, maximum deadline, lowest cost, etc.). When there are two or more criteria, the decision is referred to as a multiple-criteria decision and the problem of choice has to take the relative importance of each criterion into account. Making decisions based on a set of actions based on potentially conflicting criteria is known as multiple-criteria decision-making (MCDM) (Yoon & Hwang, 1995).

To aid decision makers facing this type of decision, some multiple-criteria support methods have been created. Multiple-criteria methods give decision makers the help they need to arrive at the best solution for their requirements. These methods allow criteria that cannot be transformed into financial values to be evaluated. They are useful for comparing alternative projects, policies, and courses of action and for analyzing specific projects, identifying their level of global impact, the most effective actions and those that require modifications (Stirling, 1997).

MCDM aid methods can be divided into two main schools: the French and the American.

According to Belton and Stewart (2002), the methods developed in Europe are jointly referred to as the French School of Multiple-Criteria Decision Aid (MCDA). These methods enable the preparation of a more flexible model of the problem, not considering the comparison of alternatives compulsory and not requiring the decision analyst to rank the criteria in a hierarchical structure. Ehrlich (1996) explains that these methods, instead of considering the intensity of a preference, consider the attractiveness or lack thereof (indifference), ranking sets of decision components. The most well-known methods of the French School are:

1. **ELECTRE (Elimination and Choice Translating Reality):** Created by Roy (1968), producing concordant or discordant indexes to determine the dominance of the alternatives and categorize them (Fülöp, 2005);
2. **PROMÉTHEÉ (Preference Ranking Method for Enrichment Evaluation):** Method using preference indices to determine the global intensity of preference between choices to obtain a partial or complete categorization (Fülöp, 2005);
3. **TOPSIS (Technique for Order Preference by Similarity to Ideal Solution):** Is a MCDM method that is based on measuring distances between alternatives under consideration and two bipolar reference alternatives, a positive and a negative ideal. Thus, the criteria used for the evaluation of alternatives should be described using strong scales (Wachowicz & Błaszczyk, 2012);
4. **MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique):** A method that adds concepts from the American and French schools (Salomon, 2004), in which models of linear programming problems are used to describe the degree of preference of the alternatives. It was developed by Bana, Costa and Vansnick (1997), presented in Costa and Chagas (2004). It allows diverse assessment criteria to be added to a single summarized criterion by attributing weights to the various criteria, respecting the opinions of the decision makers;
5. **SAW (Simple Additive Weighting):** Consists of quantifying the values of the attributes (criteria) for each alternative, constructing the Decision Matrix, which contains these values, deriving the normalized Decision Matrix, defining the importance (weights) for the criteria and calculating the global count for each alternative. The alternative with the highest count is then selected as the preferred one (Janic & Reggiani, 2002).

The main methods of the American School are:

1. **MAUT (Multi Attribute Utility Theory):** Introduced by Keeney and Raiffa (1976), this method consists of a natural extension of the Utility Theory (Fishburn, 2000) for the context in which each alternative is described by a list of attributes. The Utility Theory assumes that the decision maker wishes to make a choice that corresponds to the highest level of satisfaction (or utility). The decision maker's satisfaction or preference regarding the risk is represented by a mathematical function called the utility function;
2. **SMART (Simple Multi-Attribute Rating Technique):** Based on the use of the linear utility function as the algebraic median weighted to prioritize the alternatives. The SMART technique is based on a linear additive model. This means that an overall value of a given alternative is calculated as the total sum of the performance score (value) of each criterion (attribute) multiplied by the weight of that criterion (Doran, 1981);
3. **TODIM (Multi-criteria Interactive Decision-making):** Incorporates preference patterns of the decision makers when facing risk, based on the Prospect Theory, which uses value functions to explain risk aversion and risk seeking in decision-making (Rangel & Gomes, 2007); prospect should be understood as a game in which the decision maker prefers to gain less, when faced by a risk of losing, or run the risk of gaining in the certainty of losing (Clemen & Reilly, 2001);
4. **AHP (Analytic Hierarchy Process):** In contrast with the MAUT, it has a more simple decision modelling process and its participation in the structuring of the problem. The AHP has an additional procedure to verify the consistency of the indicated preferences. The consistency index was projected to warn the decision-making agent of possible inconsistencies in the comparisons, being given a value of zero for a perfect consistency. The AHP model allows an inconsistency level of 0.10 or less. It is a very popular method, used in many published works, including those of Saaty (1978), Fong and Choi (2000), Dobi, Gugic and Kancijan (2010), and Balubaid and Alamoudi (2015);

5. **TODA (Trade-off Decision Analysis):** Developed by Meireles and Sanches (2009), this model emerged as an alternative to the AHP and has a simpler decision-making process in that it avoids the complex procedure to verify the consistency of preferences. This method is used in this study and has been discussed and used in some academic works, including those of Rossoni (2011) and Rossoni and Meireles (2011), Vogt et al. (2015), Donofrio (2015), and Hein et al. (2015).

TODA MULTIPLE-CRITERION DECISION MODEL

According to Meireles and Sanches (2009), who proposed the T-ODA, it is a method that aids MCDM, based on three principles of analytical thinking:

- Construction of hierarchies as the problems can be broken down to hierarchical levels as a way of understanding and evaluating it;
- Establishment of priorities using a Trade-off matrix with a certain focus (objective function); and
- Observation of absolute logical consistency that is induced by the process of establishing priorities.

According to the authors, in the construction and use of a model to establish priorities based on the TODA, the following steps are taken:

1. Specification of the goals of the decision;
2. Specification of considered alternatives;
3. Definition of the choice criteria;
4. Comparison of criteria for establishing the weights;
5. Relative values via trade-off of the values of the alternatives;
6. Calculation of the objective function and choice.

Rossoni (2011) showed that the TODA method generates similar results to the AHP, which is considered as the competing model. The TODA method, however, is simpler in that it dispenses with the complex calculations that the AHP method uses to obtain the consistency index. In the TODA, these calculations do not exist and consistency is assured through the "comparison pivot."

The weighting of the criteria is a fundamental stage of any method that uses it. According to Hyde et al. (2004), the frequent subjectivity, ambiguity, and inaccurate nature of the evaluations of weights for criteria and performance of alternatives reveal uncertainty in the results of the decision analysis. The weight of the criteria is generally treated as deterministic for the evaluation of the alternatives. However, the information on the probable modification of the results if the parameters are changed is not always made available to the decision makers.

According to Wolters and Mareschal (1995), the uncertainty of these parameters influences the result and should be taken into consideration as part of the decision-making process. The TODA method establishes a consistent comparison of all the criteria using the trade-off method.

In the study of Rossoni (2011), which showed that the TODA method generates similar results to the AHP, 11 cases were analyzed using document research, including articles published in conference proceedings and journals. The problem was resolved using the AHP and the TODA method and the results of these analyses are shown in Table 1. There is no difference between the solutions. Of the eleven cases, with 38 options, 36 (94.74%) were matched.

The results of Rossoni (2011) show that there is no significant difference between the responses provided by the two methods. The Wilcoxon test showed that the ranks of both samples do not differ significantly (p-value: 0.9999).

In this work, the TODA method is presented through a case study using software available at www.decisiontoda.com. The TODA method was used because, although its results are similar to

Table 1. Result of the eleven cases – AHP versus TODA

	TODA		AHP		=
	Value	Rank	Value	Rank	
Case 1	22.53	3	26.13	2	
	23.74	2	25.35	3	
	53.73	1	48.52	1	*
Case 2	26	2	26	2	*
	53	1	49	1	*
	21	3	25	3	*
Case 3	4.7	3	3	3	*
	30.3	2	30.7	2	*
	65	1	66.3	1	*
c 4	46.48	1	67.9	1	*
	27.52	2	32.1	2	*
Case 5	22.84	3	22.65	3	*
	33.93	1	32.91	1	*
	30.78	2	29.43	2	*
	13.45	4	15	4	*
Case 6	47.78	1	44.2	1	*
	18.65	3	19.2	3	*
	30.94	2	29.3	2	*
	3.62	4	6.7	4	*
Case 7	32.93	2	33.9	2	*
	30.34	3	31	3	*
	36.73	1	35.1	1	*
Case 8	0.156	3	0.143	3	*
	0.184	2	0.163	2	*
	0.153	4	0.142	4	*
	0.258	1	0.19	1	*
	0.149	5	0.137	5	*
	0.1	6	0.098	6	*
Case 9	20.77	3	45.68	3	*
	18.74	4	42.95	4	*
	25.48	2	53.05	2	*
	36.02	1	59	1	*
Case 10	35.59	1	37.47	1	*
	30.27	3	30.4	3	*
	34.14	2	32.13	2	*
Case 11	8.95	3	14.65	3	*
	64.36	1	57.95	1	*
	25.69	2	27.41	2	*

Source: Rossoni (2011).

those of the AHP, it is easier to operate and uses the concept of causality, expressed by the Emach variable to define the importance and final weight of each criterion.

METHODS

Type of Study

This study is an application of the TODA MCDM method. The methodology employed has a constructivist approach. According to Roy and Vanderpooten (1997), this approach can be described by the efforts of researchers oriented by concepts, models, axioms, properties, and procedures.

Procedures

Following the research of the criteria of the cars, as shown in Table 2, the TODA software was downloaded from www.decisiontoda.com.

Data Treatment

The data were submitted to the TODA to aid the decision-making process. The software was operated by consensus, involving five salespeople. The weighting of the criteria and of the alternatives can be seen below.

Limitations and Difficulties

This work demonstrates the applicability of the TODA method within a specific context. As it is a single application, using the case study method, this work has limitations in the sense that, according to Yin (1989), the results cannot be generalized. The difficulty in reproducing the case lies in the developed process, considering that the weighting of the criteria was done by consensus, which is not a guarantee that a similar result will be obtained in similar cases.

ANALYSIS

The analysis was initially conducted using the TODA method, followed by the AHP for comparison.

TODA Analysis

This section contains a description of a MCDM case with the aid of the TODA software.

Specification of the Goals of the Decision

To show the potential of the TODA method, it was decided that it should be applied to the process of choosing an economy car to be used by salespeople.

In Brazil, economy cars are a category of vehicle created for people on low incomes. There are incentives to purchase them, such as tax reductions. The case consists of selecting the most suitable of the 11 cars listed in Table 2, considering the six criteria. The definition of the type of car is important because it is to be used in a fleet of cars for the salespeople, and the board of directors believes that it is important to have good fuel economy and a large trunk.

Specification of Considered Alternatives

Initially, the eleven available alternatives were introduced (the normal version of the software can handle up to 15 alternatives). They refer to economy cars with an engine up to 1000 cc. The alternatives that were introduced can be viewed in Figure 1.

Table 2. Alternatives and criteria for the case study using the TODA method

Make and Type	Price (R$)	Doors (#)	Design (Likert 1-5)	Trunk (Litres)	Fuel (Consumption Litres/100 km)	Motor Power (HP)
Chery QQ	31900	2	3	190	7.63	69
Chevrolet Celta	34950	4	3	260	5.65	78
Chevrolet Classic	34250	4	5	390	7.58	78
Fiat Palio	24730	2	3	290	5.85	75
Fiat Uno	23230	2	3	280	6.41	75
Nissan March	30990	2	3	265	7.94	77
Renault Clio	35900	2	4	255	6.8	80
Renault Sandero	34070	4	4	320	6.21	80
VW Gol	30230	2	5	285	7.19	76
VW Take Up	30560	2	3	285	6.99	82
Yundai HB20	38900	4	4	300	7.09	80

Figure 1. Introducing the alternatives
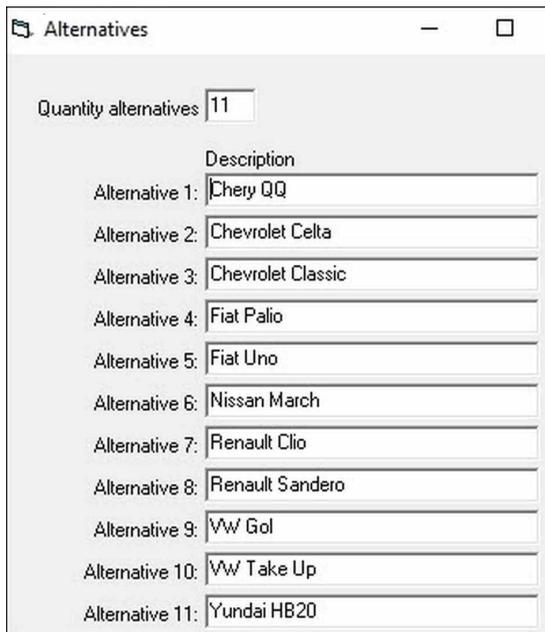
Definition of the Choice Criteria

The software solicits evaluation criteria and the respective positive or negative signal. In its normal form, the software accepts up to 15 criteria. In this example, six criteria are considered (see Figure 2):

1. Price in $, the higher the price, the worse, for which the signal is -
2. Number of doors; the company managers believe that with more doors the car is less safe and requires more maintenance, and for this reason the signal is -

Figure 2. Introduction of criteria and respective signals

3. Design on a Likert scale (1-5): this is a subjective value and was included because it is understood that it is a relevant criterion for the company's clients; the higher the evaluation the better, and for this reason the signal is +
4. Trunk space in litres: an important feature, as the salespeople will carry product samples; the larger the better, and thus the signal is +
5. Fuel consumption on the road in litres / 100 km and, in this case, the more litres required for a car to do 100 km, the worse it is, and the sign should be negative -
6. Motor power, a requirement of the salespeople, who argue that higher power means greater safety; the signal is +
7. The Weight column for each criterion is automatically filled after the "Consistent comparison of criteria for establishing the weights."

Consistent Comparison of Criteria for Establishing the Weights

The weight of each criterion in the TODA method is defined in the following stage through a prioritization matrix, as shown in Figure 3. The TODA aids the decision maker, helping to define the importance of each criterion. The software provides a matrix and, by clicking on a cell, a comparison emerges and should be marked.

In the example shown in Figure 3, a comparison is made between the price of the car and the number of doors. The five salespeople that conducted the analysis, by consensus, decided that the price was more important. Carli et al. (2008), Scarpi (2010), Dong et al. (2010), Vittikh (2015) and many other authors recommend that the comparison of factors, two by two, should be consensual. When the comparison has been made, the cell is automatically filled with the flip value, i.e., if the price is more important than the number of doors (score 5), the number of doors is, logically, less important (score 1/5). Therefore, the decision maker is called upon only to compare the upper cells of the matrix.

With all the comparisons completed, the matrix is presented as shown in the example in Figure 4. To know which weighting is attributed to the criteria, this sub-process should be completed by clicking on the Analyze button. Figure 5 shows the final weighting of the criteria. The analysis of the weighting works with two important concepts: the prioritization Matrix and the Emach Indicator. Scarpi (2010) shows how the Prioritization Matrix is applied. The TODA software is in the following stages.

Figure 3. First comparison and reverse comparison
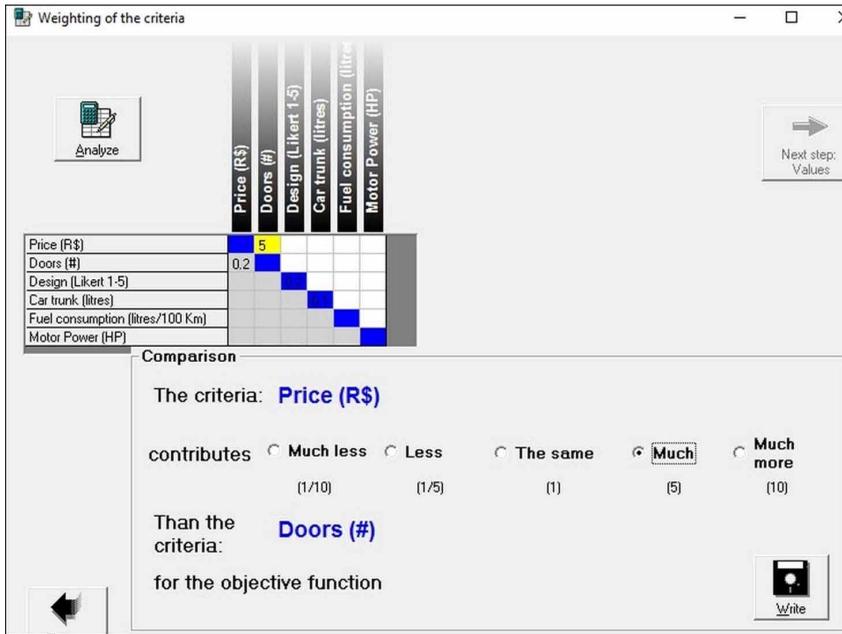
Figure 4. Completed prioritization matrix of the criteria

Step 1

In this step, the problem must be defined correctly so that the comparison of the alternatives is coherent. The decision makers must know what the function is. In this case, it is to select the best car for the fleet to be used by salespeople.

Step 2

Complete the Prioritization Matrix. In the example, the prioritization matrix is empty, in Figure 3. The elements to be compared are placed in an N x N matrix. As there are six elements to prioritize,

Figure 5. Data and analysis for weighting the criteria

	Price (R$)	Doors (#)	Design (Likert 1-5)	Car trunk (litres)	Fuel consumption (litres)	Motor Power (HP)	Points to Row	Normatization H 0-5	Emach	Analytical Weights	Relative Weights
Price (R$)		5	10	5	0.2	1	21.2	2.98	-0.82	9.68	0.2119
Doors (#)	0.2		5	0.2	0.1	0.2	5.7	0.70	0.82	6.72	0.1471
Design (Likert 1-5)	0.1	0.2	0.2	0.2	0.1	0.1	0.9	0.00	4.00	1.00	0.0219
Car trunk (litres)	0.2	5	5		0.2	0.2	10.7	1.44	-0.23	8.61	0.1884
Fuel consumption (litres/100 Km)	5	10	10	5		5	35	5.00	-1.00	10.00	0.2189
Motor Power (HP)	1	5	10	5	0.2		21.2	2.98	-0.82	9.68	0.2119
Points to Column	6.5	25.:	40.:	15.:	0.8	6.5					
Normatization V 0-5	0.7:	3.1:	5.0:	1.8:	0.0:	0.7:					

in this case, the matrix is 6 x 6. It should be observed that the diagonal, which is the meeting of the criterion on one line with the same criterion in the respective column, is neutralized. For this purpose, the cells should be painted with a bright color.

Step 3

Make the comparison using the comparison formula. This formula can be seen in Figure 3, and contains the text used to compare the two criteria. In the example, the following formula can be seen:

Criterion Y contributes
    much more (10);
    more (5);
    the same (1);
    less (0,2);
    much less (0,1)
than criterion X
    to the objective function

The comparison of the criteria in each line with the criteria of each column considers the contribution of the criterion to the objective function. For example, when comparing the Price of the car with the number of Doors, the following procedure is used:

The *Price* criterion contributes
    more (5);
than the *Number of Doors*
    to the objective function

In this case, the value of 5 was placed in the cell corresponding to the compared criteria. It is recommended that the Prioritization Matrix should be operated with the consensus of three to five people who are familiar with the circumstances of the problem and who arrive at a single result following evaluation.

The software automatically completes the cell below (or to the left of) the diagonal, considering that in the column the reverse scores are written and transposed on the corresponding line. For instance, the first line has the values (5)(10)(5)(0.2)(1). The first column will have the reversed transpose values, i.e., (1/5)(1/10)(1/5)(1/0.2)(1/1) or, in simplified form: (0.2)(0.1)(0.2)(5)(1). This can be seen in Figure7.

Step 4

Calculate the ranking obtained. In this step, the points for each line are added. It should be observed that all the values are added before and after the diagonal, line by line. This is shown in the column market "Points to Row" in Figure 5. The process is repeated for each column, adding the values that are written in the line marked "Points to Column".

Step 5

Normalize the sums of the points. In Figure 5, the column marked "Normalization H 0-5" is the normalization of the "Points to Row" column in the 0 to 5 intervals. The line marked "Normalization V 0-5"is the normalization of the "Points to Column" line in the interval of 0 to 5. The normalization of zero to five is achieved by using the in-Max Normalization formula, as can be seen in Saranya and Manikandan (2013):

$$I_p = 5\frac{p - \min}{\max - \min}$$

where p is the number of points, *min* the lowest value of points observed; *max* the highest value observed. *Min* and *max* are, respectively, in this case, for the "Points to Row", 0.7 and 35.

Step 6

With the normalized H and V values, the value of the Emach can be calculated. This is a causal indicator used to identify which criterion is most important for achieving the objective function. For further information, see Sanches et al. (2014).

As shown in Figure 5, for each criterion it is possible to obtain a pair (H, V). For example, for the "Price $" criterion, there is the pair (2.99; 0.7); for the "Doors #" there is (0.73; 3.1). The H value is considered as the causal unfolding, i.e., the loading of the criterion to respond to (be responsible for) the objective function. The V value can be considered a symptom, or unfolding, of the effect on the event in question: V is essentially a passive value.

With the H and V outputs in the Prioritization Matrix, the value of the Emach is calculated for each criterion. This value, named so in a homage to Ernst Mach, is calculated using the following formula:

$$Emach_{HV} = \frac{V}{H+1} - 1$$

The Emach expresses the sense and power of the criterion in a cause and effect relationship (Sanches et al. 2014), where the effect is the objective function. Causal criteria have a negative Emach and effect criteria have a positive Emach. The Emach limits are -1 (root cause) and 4, principal symptom of effect. Figure 5 shows that the "Fuel consumption" criterion is the main criterion that contributes to the objective function. The criterion that makes the least contribution is "Design".

Step 7

Convert the Emach values into weights. The column marked "1-Normalization" contains the Emach values normalized between 0and 1. The formula for the normalization, in this case, is:

$$Norm = \frac{4 - Emach}{5}$$

For example, the normalization of Emach value -0.82 corresponding to "Price \$" is:

$$Norm = \frac{4 - (-0.82)}{5} = 0,964$$

Step 8

Calculate the weight for each criterion. The weight of each criterion is nothing more than the normalized value multiplied by 10. Thus, with the Emach value as the origin, the weight of the criterion is calculated as:

$$Weight = \frac{10 * (4 - Emach)}{5} = 2 * (4 - Emach)$$

Thus, the relative weights of the criteria for the objective function are established. These weights are passed to the criteria window, as shown in Figure 6.

Thus, the list of criteria and relative weights is obtained, calculated rationally via trade-off, to aid decision-making.

Relative Values Via Trade-Off of the Values of the Alternatives

The next step is the introduction of the real values for each criterion. For instance, as shown in Figure 7, the values introduced are the values observed in practice, without any transformation. The same occurs for the other criteria: the constant values in Table 2 are introduced.

Figure 6. Window of criteria with respective weights
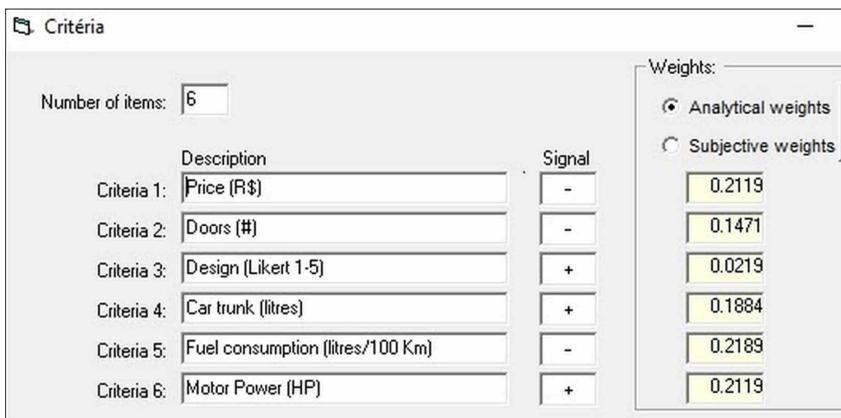
Figure 7. Window for introducing the values of the alternatives for the price criterion

These absolute values are converted into relative values through the Prioritization Matrix, which uses a trade-off process, in accordance with Steps 1 to 4, described above, constituting the coefficients of the objective function. Table 3 shows the results for the Price criterion. The price of the most expensive car in the objective function has a value of 0.114, and the cheapest has a value of 0.058.

Calculation of the Objective Function and Choice

Once all the values have been added, click on the Solve button and the final result will appear, as shown in Figure 8. The result shows two values: maximization of the objective function and minimization of the objective function. In the present study, the maximizing results recommend the Fiat Palio.

The values of the objective function for each alternative are in the Result column of Figure 8. The highest value (-0.31) is for the Fiat Palio, which is recommended as the best alternative by the TODA software and is followed by the Fiat Uno, with -0.45 points. In this analysis, the least recommended choice of car was the Yundai HB20.

Table 4 shows a summary of the calculation process used by the TODA. In line 26, Columns C to H, the weights and signals of the criteria are listed (see Figure 6). The calculation of these weights is shown in Figure 5.

In lines 2 to 12 of Columns C to H, the actual values of the criteria for each alternative are shown.

In lines 14 to 24 of Columns C to H, the relative values of the criteria for each alternative are shown. The values for Price (Lines 14 to 24 of Column C) were calculated as described in Table 3. The remaining values (Lines 14 to 24 of Columns D to H) were calculated in a similar fashion.

Lines 28 to 38 of Columns C to H show the product of the values of each alternative (Lines 14 to 24 of Columns C to H) by the respective weight in Line 26 (Columns C to H). The values of each line (Lines 28 to 38) appear added in Column I. This is the result of the objective function. The highest value (-0.403) is for the Fiat Palio; the lowest for the Chery QQ.

Table 3. Relative values through the prioritization matrix (price)

Price R$		QQ	Celta	Classic	Palio	Uno	March	Clio	Sandero	Gol	Take Up	HB20	Sum	Relative Values
		31900	34950	34250	24730	23230	30990	35900	34070	30230	30560	38900		
Chery QQ	31900		0.91	0.93	1.29	1.37	1.03	0.89	0.94	1.06	1.04	0.82	10.28	0.092
Chevrolet Celta	34950	1.10		1.02	1.41	1.50	1.13	0.97	1.03	1.16	1.14	0.90	11.36	0.102
Chevrolet Classic	34250	1.07	0.98		1.38	1.47	1.11	0.95	1.01	1.13	1.12	0.88	11.11	0.099
Fiat Palio	24730	0.78	0.71	0.72		1.06	0.80	0.69	0.73	0.82	0.81	0.64	7.75	0.069
Fiat Uno	23230	0.73	0.66	0.68	0.94		0.75	0.65	0.68	0.77	0.76	0.60	7.21	0.058
Nissan March	30990	0.97	0.89	0.90	1.25	1.33		0.86	0.91	1.03	1.01	0.80	9.96	0.089
Renault Clio	35900	1.13	1.03	1.05	1.45	1.55	1.16		1.05	1.19	1.17	0.92	11.70	0.105
Renault Sandero	34070	1.07	0.97	0.99	1.38	1.47	1.10	0.95		1.13	1.11	0.88	11.05	0.099
VW Gol	30230	0.95	0.86	0.88	1.22	1.30	0.98	0.84	0.89		0.99	0.78	9.69	0.087
VW Take Up	30560	0.96	0.87	0.89	1.24	1.32	0.99	0.85	0.90	1.01		0.79	9.81	0.088
Yundai HB20	38900	1.22	1.11	1.14	1.57	1.67	1.26	1.08	1.14	1.29	1.27		12.76	0.114

Figure 8. Final results provided by the TODA

Results

Analytical weight

Alternatives	Results
▶ Fiat Palio	-0.31
Fiat Uno	-0.45
VW Take Up	-0.88
VW Gol	-0.98
Renault Clio	-1.38
Nissan March	-1.49
Chevrolet Classic	-1.68
Renault Sandero	-1.72
Chevrolet Celta	-2.10
Chery QQ	-2.17
Yundai HB20	-2.45

AHP METHOD

This method was originally created by Saaty (1990) in the 1970s, and was developed and used intensively over the next twenty years. Although it was very popular and attracted many supports, according to Gomes et al. (2003), the method was often subject to criticisms, which will be addressed in the following section.

The AHP is a multiple criteria method to aid decision-making, proposed by Saaty in the late 1960s. It seeks straightforward solutions to problems involving complex choices. According to Saaty (1990), the method is based on three principles of analytical thinking: (1) modeling the problem as a hierarchy: in the AHP method, the problem is broken down into hierarchical levels to understand and evaluate it better; (2) establishing priorities: the adjustment of priorities in the AHP is based

Table 4. Summary of the results (TODA)

A	B	C	D	E	F	G	H	I
Line 1	Criteria → Make and Type ↓	Price (R$)	Doors (#)	Design (Likert 1-5)	Trunk (Litres)	Fuel Consumption (l/100 km)	Motor Power (HP)	TODA
Line 2	Chery QQ	31900	2	3	190	7.63	69	Actual values observed
Line 3	Chevrolet Celta	34950	4	3	260	5.65	78	
Line 4	Chevrolet Classic	34250	4	5	390	7.58	78	
Line 5	Fiat Palio	24730	2	3	290	5.85	75	
Line 6	Fiat Uno	23230	2	3	280	6.41	75	
Line 7	Nissan March	30990	2	3	265	7.94	77	
Line 8	Renault Clio	35900	2	4	255	6.8	80	
Line 9	Renault Sandero	34070	4	4	320	6.21	80	
Line 10	VW Gol	30230	2	5	285	7.19	76	
Line 11	VW Take Up	30560	2	3	285	6.99	82	
Line 12	Yundai HB20	38900	4	4	300	7.09	80	
Line 13								
Line 14	Chery QQ	0.092	0.065	0.074	0.059	0.103	0.081	Relative values
Line 15	Chevrolet Celta	0.102	0.138	0.074	0.083	0.074	0.093	
Line 16	Chevrolet Classic	0.099	0.138	0.129	0.130	0.102	0.093	
Line 17	Fiat Palio	0.069	0.065	0.074	0.094	0.077	0.089	
Line 18	Fiat Uno	0.058	0.057	0.065	0.081	0.078	0.080	
Line 19	Nissan March	0.089	0.065	0.074	0.085	0.108	0.091	
Line 20	Renault Clio	0.105	0.065	0.102	0.082	0.091	0.095	
Line 21	Renault Sandero	0.099	0.138	0.102	0.105	0.082	0.095	
Line 22	VW Gol	0.087	0.065	0.125	0.092	0.096	0.091	
Line 23	VW Take Up	0.088	0.065	0.074	0.092	0.094	0.098	
Line 24	Yundai HB20	0.114	0.138	0.106	0.098	0.095	0.095	
Line 25								
Line 26	Weight and signal of the criteria →	-0.212	-0.147	0.022	0.188	-0.219	0.212	TODA
Line 27		Objective function						Result
Line 28	Chery QQ	-0.019	-0.010	0.002	0.011	-0.023	0.017	-2.169
Line 29	Chevrolet Celta	-0.022	-0.020	0.002	0.016	-0.016	0.020	-2.103
Line 30	Chevrolet Classic	-0.021	-0.020	0.003	0.024	-0.022	0.020	-1.676
Line 31	Fiat Palio	-0.015	-0.010	0.002	0.018	-0.017	0.019	-0.310
Line 32	Fiat Uno	-0.012	-0.008	0.001	0.015	-0.017	0.017	-0.449
Line 33	Nissan March	-0.019	-0.010	0.002	0.016	-0.024	0.019	-1.487
Line 34	Renault Clio	-0.022	-0.010	0.002	0.015	-0.020	0.020	-1.381
Line 35	Renault Sandero	-0.021	-0.020	0.002	0.020	-0.018	0.020	-1.721
Line 36	VW Gol	-0.018	-0.010	0.003	0.017	-0.021	0.019	-0.988
Line 37	VW Take Up	-0.019	-0.010	0.002	0.017	-0.020	0.021	-0.878
Line 38	Yundai HB20	-0.024	-0.020	0.002	0.018	-0.021	0.020	-2.452

on the ability of a human being to perceive the relationship between objects and situations, making pairwise comparisons through a certain focus or criterion (parity treatment); (3) logical consistency: using the AHP method, it is possible to evaluate the prioritization model in terms of its consistency.

This method is widely known and an analysis of the present case using the AHP model produced the final result shown in Table 5. It should be highlighted that the same relationships were maintained regarding the relative importance of the choice criteria in both models, although the observed consistency index (CI) was 0.1726, with a Maximum Eigen Value=6.863.

According to the AHP method, the best result is the Fiat Palio, and the worst is the Chery QQ.

Comparative Analysis of the TODA and AHP

Table 6 shows a comparative analysis of the results of the two methods (TODA and AHP) for the case in question. Both recommend the choice of the Fiat Palio, with the Fiat Uno in second place, considering the adopted criteria and weights. The outputs of the two methods (TODA and AHP columns) were converted respectively into stochastic values:

$$\left[S_i = \frac{x_i - \min}{\max - \min} \right]$$

in the interval [0; 1], designated Stochastic t and Stochastic a. There is a very significant correlation at the significance level of 0.05 between the variables Stochastic t and Stochastic a (Spearman's correlation test, rs=0.6091, p-value: 0.0466). No significant difference was observed at the significance level of 0.05 between the Ranks of the results for the variables Rank t and Rank a. Rank 1 was attributed to the item preferred by the method and Rank 11 to the least preferred item. Both methods had largely similar results (Wilcoxon test, p-value bilateral: 0.8590).

Table 5. Summary of the results (AHP)

Criteria → Make and Type ↓	Price (R$)	Doors (#)	Design (Likert 1-5)	Car trunk (Litres)	Fuel (Consumption l/100Km)	Motor Power (HP)	AHP
Weight and Signal of the Criteria →	**-0.186**	**-0.042**	**0.020**	**0.083**	**-0.483**	**0.186**	
	Objective Function						Result
Chery QQ	-0.017	-0.003	0.002	0.005	-0.049	0.015	-0.0471
Chevrolet Celta	-0.019	-0.006	0.002	0.007	-0.036	0.017	-0.0350
Chevrolet Classic	-0.018	-0.006	0.003	0.010	-0.049	0.017	-0.0425
Fiat Palio	-0.013	-0.003	0.002	0.008	-0.038	0.016	-0.0279
Fiat Uno	-0.012	-0.003	0.002	0.007	-0.041	0.016	-0.0309
Nissan March	-0.016	-0.003	0.002	0.007	-0.051	0.017	-0.0448
Renault Clio	-0.019	-0.003	0.002	0.007	-0.044	0.017	-0.0392
Renault Sandero	-0.018	-0.006	0.002	0.008	-0.040	0.017	-0.0356
VW Gol	-0.016	-0.003	0.003	0.008	-0.046	0.017	-0.0383
VW Take Up	-0.016	-0.003	0.002	0.008	-0.045	0.018	-0.0369
Yundai HB20	-0.021	-0.006	0.002	0.008	-0.045	0.017	-0.0443

Table 6. Comparative analysis of the TODA and AHP results

Method →	TODA			AHP		
Alternatives↓	Result t	Stochastic t	Rank t	Result a	Stochastic a	Rank a
Fiat Palio	-0.31	1.000	1	-0.028	1.000	1
Fiat Uno	-0.45	0.935	2	-0.031	0.840	2
VW Take Up	-0.88	0.734	3	-0.037	0.529	5
VW Gol	-0.98	0.687	4	-0.038	0.456	6
Renault Clio	-1.38	0.500	5	-0.039	0.408	7
Nissan March	-1.49	0.449	6	-0.045	0.118	10
Chevrolet Classic	-1.66	0.369	7	-0.042	0.239	8
Renault Sandero	-1.72	0.341	8	-0.036	0.599	4
Chevrolet Celta	-2.10	0.164	9	-0.035	0.630	3
Chery QQ	-2.17	0.131	10	-0.047	0.000	11
Yundai HB20	-2.45	0.000	11	-0.044	0.144	9

It should be highlighted that the results are specific to the aforementioned criteria considering the assumed weights. Thus, there is no value judgement (appreciation or depreciation) with regard to the makes of car.

CONCLUSION

This study, albeit in summarized form, presents the foundations of MCDM using TODA software, which is available at www.decisiontoda.com. It is a simple method to apply, although it requires the consensus of decision makers to define the weights of the criteria. This appears to be the strong point of the method, as it uses the concept of causality, employing the Emach indicator to define the importance of each criterion to the objective function.

To Detoni (1996), the weighting of criteria by a determined procedure (direct score, swing procedure, or trade off procedure) is not simple. The TODA method facilitates the weighting of the decision criteria, enabling decision makers at small and micro enterprises to act intuitively.

In accordance with a previous study (Rossoni 2011), no difference was found in the results of the TODA and AHP methods in relation to this case. This aspect highlights the practical utility of this work concerning the diffusion of the TODA MCDM method which, given the fact that it is easy to apply, appears to be adequate for small and micro businesses that do not have human and material resources capable of applying more refined and complex methods.

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Cida Sanches is a researcher and teacher at the Administration Master's and Doctoral Programmes at FACCAMP. She graduated in psychology and has Ph.D in Health Management from the Federal University of São Paulo / Paulista School of Medicine. Has Post-doctorate from the National University of Cordoba in the stress area. She has experience in organizational psychology with an emphasis on coping strategy, stress and decision-making. She acts on the following subjects: people management, human development, stress and quality of life.

Samuel Ferreira Jr. is the coordinator of the Postgraduate courses of Project Management, Logistics, Digital Marketing and 3D Computer Graphics at University Center Senac. He is M. Sc. in Business Administration from FACCAMP and acts as a business consultant in the areas of Business Management. His fields of interest are techniques of decision and tools for quality.

Givaldo Santos is M. Sc. in Business Administration from FACCAMP and student of the Doctoral Program in Production Engineering at Federal University of São Carlos (UFScar). He acts as a business consultant in the areas of Cost Management and Budget Planning. His fields of interest are tools for quality and cost management.

Marisa R. Paixão, M. Sc. in Business Administration from UNIP - Paulista University, is a professor and researcher at the Institute of Social and Communication Sciences at the Paulista University. His topics of interest are personality and decision.

Manuel Meireles is researcher, professor and coordinator of the Administration Master's and Doctoral Programmes at FACCAMP. He works for companies as a consultant in the following fields: competitiveness, competitive strategy, management instruments and indicators. He has Ph.D. in Sciences in the field of Healthcare Management from the Federal University of São Paulo/Paulista School of Medicine, and Ph.D. in Production Engineering from the University of São Paulo. His fields of interest are administrative tools and performance indicators.