

SUBSTITUIÇÃO DE EQUIPAMENTOS APLICADA AO MERCADO BRASILEIRO DE AUTOMÓVEIS: UMA ABORDAGEM VIA CUSTO ANUAL UNIFORME EQUIVALENTE

Isotilia Costa Melo¹

Paulo Nocera Alves Junior²

Pedro Sahib Guimarães³

Daisy Aparecida do Nascimento Rebelatto⁴

Resumo

Este trabalho tem como objetivo a determinar o melhor momento para a substituição de um veículo automotivo, considerando os valores da tabela FIPE para todos os modelos listados, que foram fabricados no Brasil nos últimos cinco anos e que ainda estão em produção. Neste contexto, foram aplicadas ferramentas de engenharia econômica, i.e., fluxo de caixa, custo uniforme anual equivalente (EUAC), etc., resultando numa análise de investimentos em ativos imobilizado para automóveis particulares. Dentre os resultados, foi possível concluir que 90% dos veículos com valor inicial inferior a R \$ 50.000,00 apresentam a EAUC mais baixa no quinto ano (limite de horizonte de análise). Também foi observado o mesmo fato em marcas de luxo, como a Mercedes. Em resumo, este documento aponta orientações

Recebimento: 9/2/2017 - Aceite: 16/3/2018

¹ PhD Student (Production Engineering), University of São Paulo, Brazil. isotilia@gmail.com

² PhD Candidate (Production Engineering), University of São Paulo, Brazil. pnalvesjr@usp.br

³ Mechanical Engineer, University of São Paulo, Manager, ITAU BBA, Brazil. pedro.sahib90@gmail.com

⁴ PhD (Mechanical Engineering), Associate Professor, University of São Paulo, Brazil. daisy@sc.usp.br

gerais sobre o melhor momento para qualquer investidor que queira substituir o seu veículo.

Palavras-chave: Engenharia Econômica, Custo Anual Uniforme Equivalente, Mercado de automóveis brasileiro, Substituição de equipamentos.

EQUIPMENT REPLACEMENT APPLIED TO THE BRAZILIAN CAR MARKET: AN EQUIVALENT UNIFORM ANNUAL COST APPROACH

Abstract

This paper aims to determine the best time to replace an automotive vehicle, considering values of FIPE table for all listed models, that have been manufactured since the past five years and that are still in production in Brazil. In this regard, tools of economic engineering were applied, e.g. cash flow, equivalent uniform annual cost (EUAC), etc., resulting in an analysis of investments in fixed assets to private cars. Among the results, it was possible to conclude that 90% of autos with initial value below R\$ 50,000.00 present the lowest EAUC in the fifth year (horizon limit of analysis). It is a fact that is also observed in luxury brands, such as Mercedes. In summary, this paper points general directions to any investor who wants to replace his/her car at best time.

Keywords: Engineering Economics; Equivalent Uniform Annual Cost; Brazilian car market; Replacement of equipment.

Introdução

According to the latest study by the Brazilian Union of the Industry of Automotive Vehicle Components (SINDIPEÇAS), half of Brazilians already use private transport to move around (SILVA, 2013). In 2013, Anfavea (Brazilian Association of Automotive Vehicle Manufacturers) indicated that the automobile production had reached a new annual record, growing 9.9% and reaching the mark of 3,740,000 vehicles (ALVARENGA, 2014). Furthermore, in that same year, even with Government incentives, which had lowered the tax on new cars, the sales of new vehicles fell 1.6%, while the sales of used cars grew nearly 5% (PORTAL G1, 2014).

Given the current economic scenario, many Brazilians are choosing to replace their vehicles in defined periods. However, for the best trade-off, the consumer must choose the duration of this period based on the assessment of various quantitative factors, such as the depreciation of the vehicle, costs of maintenance, loss of guarantee, insurance value, and also qualitative factors, such as comfort, interior space, security and performance, among others.

As this decision of replacing a vehicle depends on several factors, the following questions may be formulated:

- 1) What is the ideal time to replace a private car?
- 2) What are the parameters that must be reviewed by the owner of the vehicle to determine how long they will wait before replacing vehicles?

To answer these questions, this paper investigates, according to the perspective of analysis of investment, what moment will bring greater economic benefit to the owner when carrying out the replacement of a private car. In order to achieve this proposal, it was searched for previous related works on academic databanks (Web of Science and Scopus). It was found only one recent paper applied to automotive market, who examined the fleet replacement of the Transport Department of North Carolina, identifying the optimal (minimum) life cycle cost (KAUFMANN et al., 2012). This may represent there is a gap of research about the theme.

To robustly analyze automotive market, data was selected from the average prices of the FIPE table (for listed models of vehicles, which is widely used as a parameter in negotiations for the purchase and sale of used cars throughout Brazil). From these data, it was carried out an analysis based on Economic Engineering and on Investment Analysis, using Equivalent Uniform Annual Cost (EUAC). The use of EUAC is justified, once it aids the decision-making among investments with different service times and it also serves to support future work on investment projects.

The theoretical background carried out based on the work of Blank and Tarquin (2012), Casarotto Filho and Kopittke (2000), Ehrlich (1977), Rebelatto (2004), Akerlof (1970), Hendel and Lizzeri (1999) and the recent papers of Peterson and Schneider (2014) and Schiraldi (2011).

This article is divided in 5 sections. The next section provides a review of key concepts for the analysis of investments. Section 3 explains the used method for data collection and data analysis. Section 4 exposes the obtained results. The last section discusses and concludes. It also addresses the encountered difficulties, limitations and proposes future studies.

Literature Review

2.1. Replacement of equipment applied to the market of durable goods

The focus of this study will be the analysis of equipment replacement applied to the car market. According to Hendel and Lizzeri (1999), an important reason to sell a used good, such as car, is to take advantage of the better quality of a new one.

In the same reasoning, Schiraldi (2011) defines that the transactions in the aftermarket occur because the quality of durable goods deteriorates with time and the owners sell their products to update their preferred quality; moreover, the required level of maintenance and/or the probability of failure grows with the age of the car, making the replacement desirable.

Schiraldi (2011) also states that, if there was no impediment, consumers would choose to maximize quality. There are no incentives to persist with the same vehicle for various periods since the quality of the asset depreciates. However, the friction to carry out the transaction, such as, for example, searching for the desired car, transactions with asymmetric information, taxes and bureaucracy, causes the replacement to be infrequent.

Thus, an analysis of the resale price of the vehicle over time to decide the ideal time to change the car is advantageous. As demonstrated by Akerlof (1970), in his studies on the used car market, the resale price is heavily influenced by information asymmetry, i.e., the seller knows more about the product than the buyer, leading to the problem of uncertainty of quality. He defines that there are good used cars ("cherries") and defective used cars ("lemons"), usually for a number of reasons, such as: driving style of the owner, quality and frequency of maintenance, accident history, etc. As these factors and their consequences are not easily verifiable, the buyers cannot know in advance whether the car they are buying is a "cherry" or a "lemon".

As the asymmetry of information is not the same for all components, the market response will be different on certain items. Peterson and Schneider (2014) demonstrate that the conditions of different parts of the same car will have heterogeneous effects in the market response. For example, adverse selection can only occur because of the condition of the engine, but not because of external conditions, such as the visible carcass of the vehicle.

As a result of the information asymmetry in certain items, less reliable vehicle manufacturers, i.e. with a history of frequent failures in these items, tend to have higher price falls because of lower trading volumes in the used car market (Hendel and Lizzeri, 1999). After all, as it is not converted into cash quickly, the price of the vehicle must be reduced enough in order to allow the transaction.

2.2. Analysis of investment

According to Blank and Tarquin (2012), there are three fundamental concepts that should be analyzed and understood for the analysis of investment projects in fixed assets (e.g. a car): the value of money at the time, the cash flow and the minimum acceptable rate of return (opportunity cost).

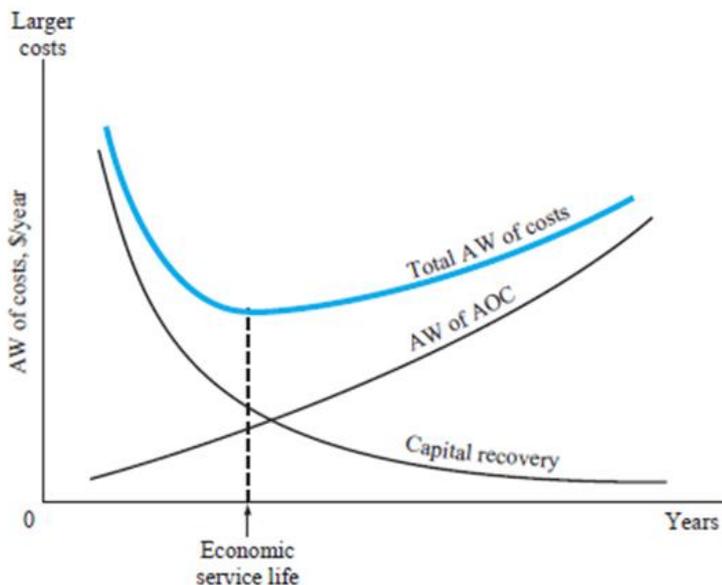
For investment in fixed assets, in addition to the primary objective of owning a private means of locomotion, there secondary objectives that comprise given status to the owner of the vehicle, such as comfort and safety, bolder design, better drivability, among others.

This study assesses the identical replacement, as defined by Casarotto Filho and Kopittke (2000), when the owner of the vehicle replaces a car for another model with similar characteristics. In this case, the most important is to determine the economic service life of the asset, for reaching the optimal time of replacement.

According to the definition of Blank and Tarquin (2012), the economic service life is the year (or years) in which the Equivalent Uniform Annual Cost (EUAC) of the asset is minimal, i.e. considering the most current cost estimates over the economic service life of all possible years that the asset can provide a necessary service and transforming them into constant cash flows, economic service life when this cash flow becomes minimum can be determined.

To solve this problem, it is necessary to have information on investment costs, vehicle depreciation, maintenance and repair of the asset. Information pertaining to the benefits generated by the good is not relevant, because, theoretically, these will be kept, as the new good is technically identical to the former one. Figure 1 represents, graphically, the EUAC and the economic service life of an asset.

Figure 1: Graphical representation of EUAC and economic shelf life (BLANK; TARQUIN, 2012)



For the choice among investment alternatives, variation of money over time must be considered. After determination of technically feasible project alternative, it is crucial to consider economic aspects. Economic Engineering is the area that provides the decision criteria for choosing among the investment alternatives (REBELATTO, 2004).

Equivalent Uniform Annual Cost (EUAC)

The EUAC compares projects with unequal lives turning mutually exclusive alternatives into an equivalent annual amount that can be used as a decision criterion, choosing the alternative that presents the lowest annual cost.

EUAC method is the best method to use, when compared to the present value, future value and rate of return, since it is the uniform annual cost of all estimated expenses and disbursements during the life cycle of the project or alternative. In addition, this measure of value in monetary units per year is easily understood by most individuals and its premises are essentially the same as the method of present value, in this way allowing

the comparison among alternatives with different useful lives (BLANK; TARQUIN, 2012).

For the calculation of EUAC, it is necessary to bring all future expenses to present value, transforming cash flow of the asset into n years, with variable values (P0,P1,...,Pn) in a single payment at the present (Equation 1), through the sum of the NPV; in this way, is turns this Sn value into a series of future uniform payments (immediate annuity) with number of years equal to the year under examination and thus it obtains a constant P cash flow for n years (Equation 2) corresponding to the total cost of the original cash flow of the asset (Figure 2).

Figure 2: Graphical representation of transformations to obtain the EUAC.

$$S_n = \sum_{k=0}^n \frac{P_k}{(1+i)^k} \tag{1}$$

$$P = \frac{i \times (1+i)^n}{(1+i)^n - 1} \times S_n = \frac{i \times (1+i)^n}{(1+i)^n - 1} \times \sum_{k=0}^n \frac{P_k}{(1+i)^k} \tag{2}$$



Source: Adapted from Blank and Tarquin (2012).

For the application of the EUAC method, there is the need for knowledge, or a precise estimation, of the value of acquisition of the asset (initial investment), the resale value of the asset, the costs of operation and maintenance for each year of the service life of the asset, in addition to the minimum attractive rate of return (MARR) to determine the cost of capital.

When it comes to the EUAC method, few studies were found in the literature with the exact term, as described earlier.

Among them, some use the EUAC incorporating it into general models for the analysis of cooling/heating systems, as in the case of Sheen (2005), who applies it to the profitability of fuzzy models of financial assessment of different alternatives for Demand Side Management (DSM) to determine solutions of lower cost for mutually exclusive alternatives,

presenting two case studies, one on the installation of an air conditioning system and the other on a system of generators with steam turbines.

Hang et al. (2011) and Mostafaeipour et al. (2014) also make economic analyses of cooling system projects, while Sanaye et al. (2010) model and make an economic analysis of heat pumps with gas engine, compared to electric motors, for home/business in dry/wet areas with hot/cold climate, taking into account consumption and costs.

Most authors use EUAC for the analysis of the cost of life cycle, maintenance and preservation of resources, as it can be seen e.g. in the works of Wang et al. (2013), Liu et al. (2010) and Irfan et al. (2009).

Regarding the application of EUAC for the replacement of equipment in large investments, Sanaye (2014) assess the replacement of approximately 570,000 "burners" in twenty-seven industries in Iran.

Stasko and Gao (2012) develop green fleet management strategies, minimizing EUAC to compute the optimal lifespan, considering the age, resale revenue, maintenance, repair, and lifetime costs of vehicles, at a discount rate. They present a dynamic programming for making vehicle purchase, resale, retrofit, and replacement decisions in a fleet management under environmental regulation.

Method

The calculation of the equivalent annual cost of the models was carried out through a spreadsheet in Excel®, in which the main indicators to be analyzed were calculated. The data that fed this spreadsheet were extracted from the FIPE table and subsequently selected according to the horizon of analysis available.

3.1 Object of Study

The values to be used for the calculation of the Equivalent Uniform Annual Cost (EUAC) were obtained from the table of average prices for vehicles that is produced by the Brazilian Economic Research Institute Foundation (FIPE). This table is generated monthly since 2000 from the price survey of new and used vehicles, and it is the most comprehensive study of its type in Brazil, being accessed by more than 3,500,000 persons every month in its on-line version, being also published in full in the *Valor Econômico* newspaper. With the survey, it can reach an average market value and, therefore, it serves as a reference for negotiations, for the calculation of the vehicle tax and also for the calculation of indemnification of insurers in all Brazil.

The Economic Research Institute Foundation (FIPE) is part of the Department of Economics, School of Economics, Administration and

Accounting (FEA) of the University of São Paulo (USP). Its role is to study the economic and social phenomena using theories and methodologies of Economy, in order to contribute to the discussion of the major economic and social indicators of the country (FIPE, 2016).

Every month, FIPE performs quotations in more than 300 authorized dealerships, fairs of used cars, on-line and printed classified ads, in addition to contacts by telephone across the country. Vehicles in bad conservation conditions or with optional equipment in addition to the normal ones from the series, which have values fairly distant from the average, are purged from the analysis. There is also an advisory council composed of various agencies that oversee the study and ensure full transparency of the methods used.

Procedures of data collection

Despite the buying and selling prices being actually charged vary depending on several factors (region, conservation, color, accessories, etc.), when using the data obtained from the FIPE table these variations are eliminated and it has the average prices of vehicles, being these prices widely used as parameter for negotiations and assessments in the national market.

The data used in this study were obtained using automated searches to the FIPE table, through programming, resulting in a base spreadsheet with all the tabulated values of all car models studied by FIPE. Data extraction was carried out on 07/Sep/2014 and resulted in 19,953 data lines related to the prices of each year for 4,473 models manufactured by 87 different car manufacturers.

After the consolidation of these data, it is analyzed the horizons of analysis available for each model. For the selection of the 227 models to be examined, it is chosen the ones with list price for the "Zero" model and continuous horizon of analysis of at least five years. In other words, they must have the list price of the "Zero" model (Year 0) and all subsequent years until at least the 2010 model (Year 5).

The higher the horizon available for the selected model, the more complete will be its analysis; however, to place all the models selected on the same basis of comparison, it is used the horizon of analysis of five years, as it provides the largest number of data for analysis, i.e., number of models vs. horizon available.

Procedures of data analysis

To define the analysis that best represents the actual situation, it is necessary to make a choice regarding its orientation and the type of expected return. Initially, the initial assumptions and categories will be validated through qualitative variables identified as relevant to the model.

The models were classified expecting to meet different depreciation rates for different manufacturers and different price ranges, as well as for items such as engine, transmission, number of doors, category of vehicle (hatch, sedan, SUV, etc.), origin of the manufacturer, among others.

Later, these parameters will be analyzed to see which ones best explain the behavior of the depreciation of a certain model or manufacturer, identifying trends that best show the reflections of information asymmetry in components not accessible to verification, that is, it was expected that less reliable brands to have more price declines as they have lower trading volumes on the aftermarket in relation to reputable brands (HENDEL; LIZZERI, 1999).

To build the complete database for the analysis, it was carried out automation with Visual Basic® to run the spreadsheet of equivalent uniform annual cost for all selected models and consolidate the results in a single table.

The end result was a spreadsheet with each of the 227 models added to the ratings and also the EUAC of each year of each vehicle. This allowed us to analyze several models simultaneously, using Pivot Tables, and to obtain charts.

The characterization, clustering and analysis of the data and given results were made in relation to the initial value, engine capacity (1.0, 1.8, 2.0, etc.), type of transmission (automatic or manual) and manufacturer.

Results

In short, as there is an increase in engine displacement, there is also an increase in the price range of the vehicle, denoted by the change in the composition of the samples of each segment of engine capacity, i.e. the increase of engine displacement is directly proportional to the increase in the initial value of the vehicle.

Regarding the type of transmission, for models up to R\$30,000 it cannot be found samples with automatic transmission and the proportion of this type of transmission in relation to manual transmission increases as the price range increases, tying at 50% at the range from R\$50,000 to R\$100,000 and surpassing in the models over R\$100,000.

Of all the manufacturers analyzed, the only one present in all price ranges is VW (Volkswagen), being more expressive in the price ranges of initial value of R\$30,000 up to R\$100,000. Fiat dominates the vehicles that are valued up to R\$30,000 in year zero, with 50% of the models in this price range; Mitsubishi has the largest share (23%) of samples in the range from R\$100,000 to R\$250,000, while Porsche holds 44% of the models above R\$250,000.

There is a predominance in models from French manufacturers (Peugeot, Renault and Citroën) in the range from R\$30,000 to R\$50,000, amounting to 48% of the models. In the price range from R\$50,000 to R\$100,000 and also from R\$100,000 to R\$250,000, the models from Oriental manufactures (Mitsubishi, Nissan, Honda and Toyota from Japan and Kia Motors from South Korea) are prevalent and amount to 32% and 52% of the models analyzed in these price ranges, respectively.

It carried out analyses of the variation of the EUAC for different data clustering, according to the initial value, engine capacity, type of transmission or manufacturer.

The result of the analysis of the average variation of the EUAC, by grouping models according to their initial value, revealed the following behavior: while vehicles with value up to R\$100,000 in year zero exhibit an ever-decreasing variation in the EUAC, vehicles in the range from R\$100,000 to R\$250,000 and greater than R\$250,000 exhibit increasing variations from the 2nd and 3rd years, respectively.

In short, it is also observed, in the average percentage variation of the EUAC of the models grouped according to engine capacity, a behavior similar to that observed in the categorization by price ranges. As expected, there are parallels between the behavior of the average variation of the EUAC of vehicles with less potent motors and those with lower initial value and vehicles with more potent motors and those with greater initial value.

The analyses of average variation of the EUAC for each type of transmission were made by dividing them also according to the value range of the vehicle in the year zero, and the models up to R\$30,000 were not included because they all have manual transmission. The average percentage variation of the EUAC for the models in the initial value ranges from R\$30,000 to R\$50,000 and from R\$50,000 to R\$100,000 is ever-decreasing, regardless of the type of transmission. For models with initial value from R\$100,000 to R\$250,000, the EUAC decreases sharply up to the third year for vehicles with manual transmission, and it is less pronounced up to the second year for vehicles with automatic transmission, growing from there.

For the analysis of the average variation of models by manufacturer, the study was divided among the various segments of initial value to better isolate the behaviors of the average variation of the EUAC for the models of each manufacturer in each initial value range.

Table 1 shows the year with the lowest variation in the EUAC for this study with a horizon of five years, divided by manufacturer and initial value. It should be noted that in Table 1 and in Figures 5 and 6, for the models between R\$50,000 and R\$100,000, the manufacturers Hyundai, Smart, Wake and Chery were grouped under "Other". In the range from R\$100,000 to R\$250,000, the manufacturers Volvo and Chrysler were grouped under "Other". It is also grouped in the category "Buggy" the manufacturers BRM, Fibravon, Fyber and Wake, manufacturers of national buggies.

Table 1: Lowest mean variation of the EUAC, grouped by manufacturer and initial value.

Manufacturer	Initial value				
	Up to 30,000	30,000 to 50,000	50,000 to 100,000	100,000 to 250,000	Above 250,000
VW	5	5	5	2	2
GM	5	5	2	-	4
Fiat	5	5	5	-	-
Ford	5	5	5	2	-
Renault	2	5	-	-	-
Peugeot	5	5	-	-	-
HAFEI	5	-	-	-	-
Kia	-	3	4	3	-
Nissan	-	5	5	5	-
Citroën	-	5	5	-	-
Buggy	5	5	-	-	-
Suzuki	-	-	2	-	-
Honda	-	-	3	2	-
JINBEI	-	-	5	-	-
Mercedes	-	-	5	5	3
MINI	-	-	-	5	-
Audi	-	-	-	5	-
Mitsubishi	-	-	5	5	-
Toyota	-	-	5	2	-
Agrale	-	-	-	3	-
BMW	-	-	-	-	4
Porsche	-	-	-	-	5
Subaru	-	-	-	-	3
Jaguar	-	-	-	-	3
Lexus	-	-	-	2	3
Maserati	-	-	-	-	3
Other	-	-	5	2	-

Source: Elaborated by the author.

It can be noted that in the range up to R\$30,000, while the manufacturers VW, Peugeot, Fiat and GM have an ever-decreasing variation in the EUAC, Ford has little variation from the third year and Renault has a growing EUAC from the second year.

Between R\$30,000 and R\$50,000, the variation of the EUAC is ever-decreasing, with the exception of Kia Motors which has a leap in EUAC from the fourth year, justified by representing the behavior of the Picanto model, which underwent a complete change of design in 2012 (year 4). Thus, as the devaluation of the 2011 model is too high (from year 3 to year 4), there is a high cost of capital because of the loss of value, causing a sharp increase in the EUAC, thus representing a case of obsolescence.

In samples with initial value between R\$50,000 and R\$100,000, there is a change of behavior in relation to the above. Although most manufacturers have average EUAC with decreasing variation, such as Nissan, JINBEI, Citroën, and Ford, this last one, with the exception of the second year when there is an increase, reaching a minimum value at the end of the fifth year, some manufacturers have little variation from the second year, such as VW and Fiat, or even growing variation in EUAC, as in the case of Kia Motors, Suzuki and Honda.

The change of behavior becomes even sharper for the range from R\$100,000 to R\$250,000, in which only Mercedes-Benz and MINI have EUAC with decreasing variation, and all other manufacturers show little variation or an increasing variation from the second or third year. In addition, for models with initial value greater than R\$250,000, most manufacturers present a growing behavior, and only Porsche shows an always negative variation in the EUAC.

As it can be observed in Table 1, only VW is present in all price ranges; therefore, its change in behavior can be analyzed according to the change in the value range studied. In the ranges up to R\$100,000, VW always demonstrates a negative variation in the EUAC, although it presents only a slight variation in the range from R\$50,000 to R\$100,000, reaching 85% of the EUAC of year 1 in the ranges up to R\$50,000. For values above R\$100,000, the variation of the average EUAC for VW models is ever-increasing from the second year. It can be seen similar behavior in the Ford models with initial value above R\$100,000.

As the EUAC can vary because of several factors, the determination of the best time to perform the replacement of the vehicle becomes a non-trivial task. To verify what year most models show the smallest EUAC or the closest to it, variation analyses were made for the EUAC for each year of the

vehicle in relation to the lowest EUAC found in the first five years, and if the variation is null this is the lowest EUAC of the model.

Figures 3 to 7 presents the results divided by the initial value ranges, plotting all samples according to their year (horizontal axis) and their percentage difference (vertical axis) in relation to the best EUAC of the model studied. The squares delimit the models that present, for each year, the value of EUAC up to 5% greater than the best EUAC found for the same model, and the value in the upper-left corner of each square indicates the percentage of samples of each year that are thus delimited.

It can be noted a change in behavior: for the models of the three initial value ranges up to R\$100,000 (up to R\$30,000, from R\$30,000 to R\$50,000 and from R\$50,000 to R\$100,000), there is a higher concentration of models with EUAC up to 5% greater than the best EUAC found for samples with five years; for the price ranges over R\$100,000 (from R\$100,000 to R\$250,000 and greater than R\$250,000) this concentration begins to migrate, being greater in the second year for models with initial value between R\$100,000 and R\$250,000 and in the third year for models with initial value over R\$250,000.

Figure 3: Variation of the EUAC in relation to the best EUAC of the model studied in the initial value range up to R\$30,000.

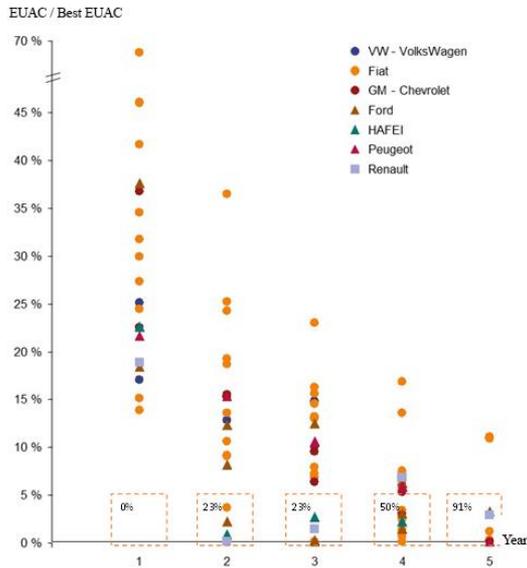


Figure 4: Variation of the EUAC in relation to the best EUAC of the model studied in the initial value range of R\$30,000 up to R\$50,000.

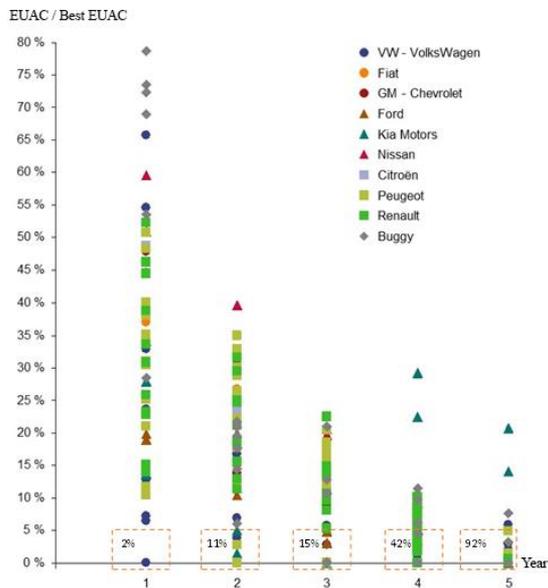


Figure 5: Variation of the EUAC in relation to the best EUAC of the model studied in the initial value range of R\$50,000 up to R\$100,000.

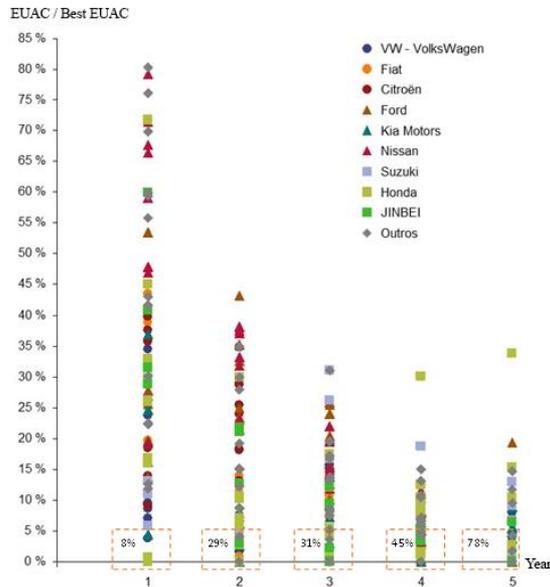


Figure 6: Variation of the EUAC in relation to the best EUAC of the model studied in the initial value range of R\$100,000 up to R\$250,000.

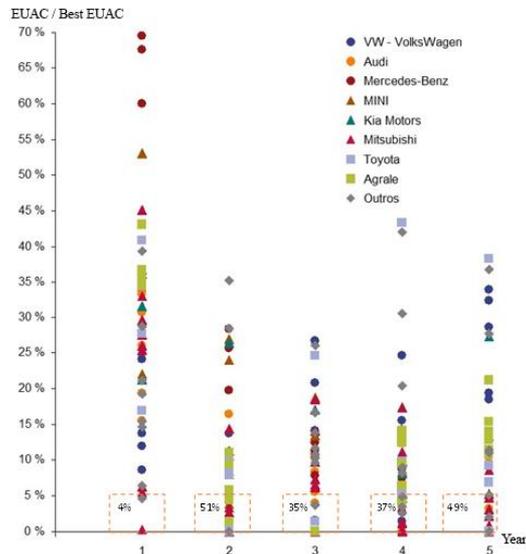
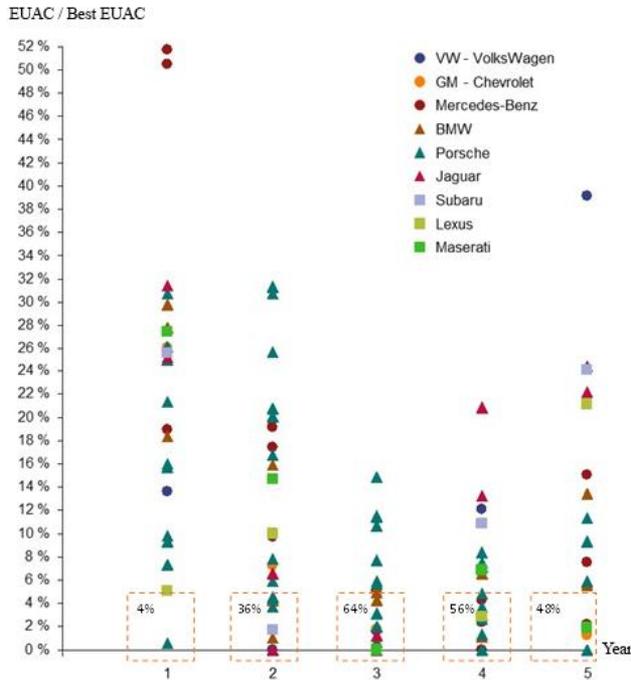


Figure 7: Variation of the EUAC in relation to the best EUAC of the model studied in the initial value range greater than R\$250,000.



Discussions

Through the study of the results obtained, it can be understood that the higher the initial value of the vehicle, more sophisticated it will be: greater engine capacity, automatic transmission, etc. It can also be noted that for vehicles with initial value of up to R\$100,000, the replacement of the vehicle will be more advantageous the longer the time of life within the horizon analyzed (up to five years of life), since most of the time the EUAC of these models is decreasing.

However, attention should be paid to the costs of maintenance, which will be increasing over time, and to the replacement of the vehicle when the costs of maintenance increase up to the point that they obfuscate the reduction of the EUAC, which in this analysis is due to the cost of capital only.

With the increase of the initial value of the vehicle, the behavior of the EUAC changes and thus the time will be lower for vehicles with higher initial value so that they present minimum EUAC. In addition, the EUAC of

vehicles with initial value above R\$100,000 most often presents a minimum point around the second or third year of life and then it increases, and it may even exceed the value of the EUAC of the first year of life. This makes the study on the replacement of this type of car even more delicate, because if the replacement is not made right in the first few years there is a risk of paying a higher EUAC for an older vehicle and propensity for greater costs of maintenance.

One hypothesis to interpret these results is that the buyer of a more expensive vehicle will prefer to buy a new vehicle instead of buying a used one. Thus, the vehicle will depreciate more quickly because of its low liquidity in the aftermarket, as buyers with lower purchasing power will only find the purchase advantageous if the price fall enough to compensate the choice of a used car in relation to less sophisticated but new vehicles, and the cost of capital for more expensive vehicles becomes greater because of the increasing devaluation, which increases the total EUAC of the vehicle.

Therefore, it is appropriate an analysis of the behavior of the Brazilian automobile market in order to identify preferences that justify the results found in this study.

Conclusions

The objective of this paper was to determine the best time to replace an automotive vehicle. It was possible to conclude that 90% of autos with initial value below R\$ 50,000.00 present the lowest EAUC in the fifth year (horizon limit of analysis). It is a fact that is also observed in luxury brands, such as Mercedes. In addition, the EUAC of vehicles with initial value above R\$100,000 most often presents a minimum point around the second or third year of life and then it increases.

During the execution of this study, some difficulties were faced to elaborate a complete analysis due to lack of open data in order to examine the variation at the national level, by region or type of reseller (dealerships, fairs, Internet, etc.), and including costs of maintenance, in addition to the price. The horizon of analysis was also a research limitation.

Taking into account these hypotheses and difficulties, for future studies, it is recommended a standardization of the costs of maintenance to include them in future analyses on the EUAC of cars and studies by region, verifying the hypothesis of how the great concentration of population and concentration of income influence the liquidity and devaluation of automobiles.

Another issue to be examined is the influence of the average income in the area, in the proportion of vehicles in each price range available for

sale. In addition, there is the need to pay also attention to the size of the aftermarket of each location, both on the supply and demand side to determine who will have greater bargaining power: the buyer or the seller.

Another important point to be noted is that this paper reviewed only a static picture of the market in September 2014 as the points were obtained from the FIPE table in a single day. It would be interesting the analysis of variance of the data over the course of a year, collecting data from the FIPE table at every monthly update and verifying the effects of seasonality on the car market and the devaluation of models shortly after the release of newer models.

References

AKERLOF, G. A. The market for “Lemons”: Quality Uncertainty and Market Mechanism. *Quarterly Journal of Economics*, v. 84, n. 3. p. 488 -500, 1970.

ALVARENGA, D. Produção de veículos cresce 9,9% em 2013 e bate recorde, diz Anfavea. *Jornal G1*. 2014. Available from: <<http://g1.globo.com/carros/noticia/2014/01/producao-de-veiculos-cresce-99-em-2013-e-bate-recorde-diz-anfavea.html>>. [Accessed: November 2016].

BLANK, L. T.; TARQUIN, A. J. *Engineering Economy* . 7. ed. New York: McGraw-Hill Companies, Inc, 2012.

CASAROTTO FILHO, N.; KOPITKE, B. H. *Análise de Investimentos*. 9. ed. São Paulo: Atlas, 2000.

EHRlich, P. J. *Avaliação e seleção de projetos de investimentos: critérios quantitativos*. 1. ed. São Paulo, Brasil: Atlas, 1977.

FIPE. *Preço médio de veículos - Consulta de carros e utilitários pequenos*. 2016. Available from: <<http://www.fipe.org.br/web/index.asp?aspx=/web/indices/veiculos/introducao.aspx>>. [Accessed November 2016].

HANG, Y.; MING, Q.; ZHAO, F.. Economical and Environmental Assessment of an Optimized Solar Cooling System for a Medium-Sized Benchmark Office Building in Los Angeles, California. *Renewable Energy*, n. 36, n. 2, p. 648-658, 2011.

HENDEL, I.; LIZZERI, A. Adverse Selection in Durable Goods Markets. *The American Economic Review*, p. 1097-1115, 1997.

IRFAN, M.; KHURSHID, M. B.; LABI, S. FLORA, W. Evaluating the Cost Effectiveness of Flexible Rehabilitation Treatments Using Different Performance Criteria. **Journal of Transportation Engineering**, v. 135, n. 10, p. 753-763, 2010.

KAUFFMANN, P.; HOWARD, E.; YAO, J.; HARBINSON, D.; BROOKS, N.; WILLIAMS, R.; GURANUS, C. Criteria for Fleet Management: Identification of Optimal Disposal Points with the Use of Equivalent Uniform Annual Cost. **Transportation Research Record: Journal of the Transportation Research Board**, v. 2292, n. 1, p. 171-178, 2012.

LIU, L., HOSSAIN, M.; MILLER, R. W. Costs and Benefits of Thin Surface Treatments on Bituminous Pavements in Kansas. **Transportation Research Record: Journal of the Transportation Research Board**, v. 2150, n.1, p. 47-54, 2010.

MOSTAFAEIPOUR, A.; BARDEL, B.; MOHAMMADI, K.; SEDAGHAT, A.; DINPASHOH, Y. Economic Evaluation for Cooling and Ventilation of Medicine Storage Warehouses Utilizing Wind Catchers. **Renewable and Sustainable Energy Reviews**, v.38, p. 12-19: 2014.

PETERSON, J. R.; SCHNEIDER, H. S. Adverse selection in the used-car market: evidence from purchase and repair patterns in the Consumer Expenditure Survey. **The Rand Journal Of Economics**, v. 45, n. 1, p. 140-154, 2014.

PORTAL G1. **Venda de carros 0km diminui 1,6% e a dos usados cresce 5% em 2013**. 2014. Available from: <<http://g1.globo.com/jornal-nacional/noticia/2014/01/venda-de-carros-0km-diminui-16-e-dos-usados-cresce-5-em-2013.html>>. [Accessed November 2016]

REBELATTO, D. A. N. **Projeto de Investimento**. 1. ed.. Barueri, São Paulo, Brasil, 2004.

SANAYE, S. An Economic Assessment of Burner Replacement in Various Industries of Iran. **Energy Sources, Part B: Economics, Planning, and Policy**, v. 9, n. 3, p. 256-265, 2014.

SANAYE, S.; AGHAEI, M.; CHAHARTAGHI, M. Modeling and Economic Analysis of Gas Engine Heat Pumps for Residential and Commercial Buildings in Various Climate Regions of Iran. **Energy and Buildings**, v. 42, n. 7, p. 1129-1138, 2010.

SCHIRALDI, P. Automobile replacement: a dynamic structural approach. **RAND Journal of Economics**, v. 42, n.2, p. 266-291, 2011.

Sheen, J. Fuzzy Financial Profitability Analyses of Demand Side Management Alternatives from Participant Perspective. **Information Sciences**, v. 169, n. 3-4, p. 329-364, 2005.

SILVA, C. Metade da População usa veículo particular. **O Estado de São Paulo**. 2013. Available from: <<http://www.estadao.com.br/noticias/impresso,metade-da-populacao-usa-veiculo-particular,1060432,0.htm>>. [Accessed November 2016]

STASKO, T. H.; GAO, H. O Developing green fleet management strategies: Repair/retrofit/replacement decisions under environmental regulation. **Transportation Research Part A**, v. 46, p. 1216-1226, 2012.

WANG, G.; MORIAN, D.; FRITH, D. Cost-Benefit Analysis of Thin Surface Treatments in Pavement Treatment Strategies and Cycle Maintenance. **Journal of Materials in Civil Engineering**, v.25, n. 8, p. 1050-1058, 2013.