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Relationship Between Vehicle Price and its Safety Ratings

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Abstract: The objective of the paper is to determine the relationship between a vehicle price and its safety ratings in the Czech Republic for vehicles sold and newly registered in the year 2022. The data collection was performed using content analysis. It was found that in 2022, Škoda Auto vehicles accounted for more than 35 % of all newly registered vehicles in the Czech Republic. The evaluation of vehicle safety was performed on the basis of results published on the EuroNCAP server. The findings were used as a basis for performing cluster analysis and correlation analysis of the data obtained. The analysis shows that even though safety plays an important role in the automotive industry, vehicle price is not a decisive factor in achieving higher safety ratings. The findings of this paper have a significant impact on consumers and automotive, showing that the price difference between vehicles does not necessarily correlate with different levels of safety. The limitation of this paper is its focus on the Czech Republic only, which may influence the generalization of the results to other markets.

Keywords: Vehicle safety, road transport, automotive, safety technologies, market trends

1. Introduction

One of the major problems of today´s world is the number of traffic accidents and deaths on roads [1]. Transport remains an integral part of modern life and the importance of road traffic safety must not be underestimated. As a result, recent studies on road safety have focused on the analysis of risk factors that influence the severity of traffic accidents [2]. The twentieth century thus saw the development of private passenger car transport; currently, the consumer considers both the price and safety when buying a car [3]. A high safety factor required for means of transport entails high costs [4]. However, clear identification of risk factors in the occurrence of traffic accidents is an important

way to increase safety on roads [5]. Vehicle safety is undoubtedly linked to traffic accidents [6]. The level of vehicle safety plays an important role in the number of traffic accidents [7]. Car manufacturers and researchers undertake considerable efforts to develop mechanisms for increasing vehicle safety. Car companies are mainly focused on primary prevention, which includes developing a positive health attitude to prevent negative health impacts [8]. Manufacturing and integration of self-driving vehicles have the potential to enhance overall transportation efficiency and safety [9]. These systems increase driver safety by providing warnings in the vehicle but require advanced transport infrastructure and are rather costly [10]. Many stakeholders, including politicians and car manufacturers, are aware of this situation and have already taken steps to tackle these safety problems and use this business opportunity [11].

The objective of the paper is to determine the relationship between vehicle price and safety ratings in the Czech Republic for vehicles sold and newly registered in 2022.

Research question 1: Which new vehicles were registered in 2022 in the Czech Republic and what is their usual price?

Research question 2: What is the safety rating of newly registered vehicles in the Czech Republic in 2022?

Research question 3: What is the average value of one safety feature of these vehicles and does vehicle price influence its safety rating?

C. Fragassa et al. [12] believe that the application of suitable vehicle construction materials represents a strategy that can enable a reduction of weight, thus increasing the efficiency and performance of vehicles; however, these construction elements cannot be applied at the expense of safety [13]. There are many ways to increase safety, such as automatic detection of traffic accidents, which can to a certain extent shorten the response time of emergency services and vehicles in the vicinity of accidents, thus improving the rescue efficiency and the level of traffic safety. However, this detection device is installed in a limited number of vehicles due to its purchase price [14]. Qualitative content analysis and similar standardized methods are sometimes viewed as technical instruments that can be used only for basic and superficial text sorting and analysis. [15]. M. S. Islam et al. [16] performed a content analysis of qualitative information from news articles, online reports, and blogs, and compared them with findings from quantitative data. M. S. Islam et al. [16] deal with studies on transportation-related life cycles, considering them vital for decision-making at different levels. Content analysis identified the most frequently discussed terms, specifically, “impact”, “transport”, “emission”, and “carbon”, which indicate current research trends and research gaps, such as consumption-related topics. V. Omahne et al. [17] apply textual analysis techniques to analyze the basic topics related to sustainable transport and measures to mitigate congestion. Statistical analysis methods represent a set of techniques and practices used to analyze data and gain insight into patterns,

relationships, and important information contained in data [18]. Problems that have affected many areas of the economy have influenced the transport sector as well. A. L. Mashkin et al. [19] present some statistical indicators characterizing transport activities and transport infrastructure. [20] describe the characteristics of transport systems in European metropolitan areas that ensure airport transport services. The authors conducted an analysis of statistical data and means of transport and compared the methods of ensuring airport transport serviceability [21].

E. Brumercikova and B. Bukova [22] employed regression and correlation analyses to evaluate the performance of public passenger transport in the Slovak Republic. They aimed at identifying an efficient strategy for enhancing passenger transport development. They performed analyses based on specific factors identified as factors influencing transport performance. During the analysis [23], calculations were conducted to derive partial correlation coefficients. These calculations confirmed a clear correlation between the volume of freight transport, the number of track sidings, and the incidence of transit traffic. J. Gnap et al. [24] used the analysis of statistical data and operational means of transport and compared the methods of transport serviceability of airports. The authors use correlation analysis, regression models, and linear correlation indices. Traffic accidents, traffic congestion and the resulting problems are of international interest. Based on the results, two major factors were identified: the willingness to share information and the need for control. [25]. H. Zou [26] argues that cluster analysis is one of the major research directions in the area of data mining, which has currently penetrated all fields and made considerable progress. Cluster analysis is important because it enables the evaluation of features by grouping similar data, with the aim of grouping elements sharing common features into homogeneous groups based on various variables [27]. J. Wu et al. [28] used cluster analysis to analyze vehicle driving data to classify the conditions of road recovery in individual municipalities during the period of the first six months after the earthquake in Fukushima. The authors used five input variables and divided the sample into five clusters using cluster analysis. V. Harantova et al. [29] deals with passenger demographics in transportation, highlighting significant differences in terms of gender, social status, and car ownership in the context of the utilization of public transport, private cars, and other alternative means of transport used for commuting to school and work.

2. Data and Methods

The major research focus is on newly registered vehicles. Data on the number of newly registered vehicles are publicly available on the official websites of the Ministry of Transport (2023), in the Road Vehicle Register section. Statistics on new and used vehicle registrations are regularly updated on monthly basis.. For the purposes of this research, the publicly available data need to be reformatted and structured, which means that it is necessary to perform a cluster analysis of the data so that they

are properly classified by key attributes. From the data, only those relevant to the present research are selected, specifically, only data on passenger vehicles for which a factory make and vehicle types are recorded. There will be considered only vehicles with more than 100 units sold in the monitored period.

A key component in the data collection process is a thorough assessment of the safety of individual vehicles sold in the given period. Information about safety ratings of vehicles sold in the European Union is available on a specialized server (EuroNCAP, 2023) [34]. By performing a quantitative content analysis, additional data regarding their safety are assigned to individual vehicles. EuroNCAP categorizes vehicles by make and model, which enables assigning safety ratings for the safety of drivers, passengers, and vulnerable road users to each selected vehicle as well as the evaluation of active safety features of the vehicles. The ratings are given points on a scale from 0 (the lowest safety level) to 100 (the highest safety level). Furthermore, a cluster analysis will be performed to describe the relationship between individual aspects of safety and the overall vehicle price.

The existence of a relationship between a vehicle´s price and its safety rating will be determined using correlation analysis.

Correlation analysis will be used to find the relationship between a vehicle's price and its safety rating.

and further compared using correlation analysis. The correlation analysis will use Pearson correlation analysis, Kendall's Tau, and Spearman correlation coefficient. The data obtained through based on the two preceding questions (the values of vehicle safety rating and vehicle price) will be processed in the statistical data analysis program "R".

For the calculation of the Pearson correlation coefficient, the following formula is used [30]:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2(y-\bar{y})^2}}, \quad [-] \tag{1}$$

where: x is value of vehicle safety [0-100 points]; $\bar{x}$ is average value of vehicle safety [sum of all x divided by the number of observations x]; y is vehicle price [points]; $\bar{y}$ is average vehicle price [sum of all y divided by the number of observations y]; α is significance level [%].

First, it is necessary to determine the significance level α, which is 5 %.

Kendall's Tau is calculated using the formula below [31]:

$$Kendall's\ Tau\ B = \frac{n_c - n_d}{n\,(n-1)/2}, \quad [-] \tag{2}$$

where: nc is number of concordant pairs [-]; nd is number of discordant pairs [-]; n is number of samples [-].

Spearman correlation coefficient is calculated using the following formula [31]:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}(r_x - rY_i)^2}{n(n^1-1)}, \quad [-] \tag{3}$$

where: *n* is the number of values in samples X and Y [-]; *rXi* order of i-th value in sample X [-]*; rY*i order of i-th value in sample Y [-].

Moreover, it is necessary to determine the weights of the resulting correlation, which will be divided into six groups – very low, low, small medium, medium, large, and very large correlation for the purposes of a better interpretation of the results.

The p-value indicates the probability of the monitored data. If the p-value is low (e.g., below 0.05), there is a very small probability that the results could be achieved if the null hypothesis is accepted. This leads to rejecting the null hypothesis in favor of accepting the alternative hypothesis stating that there is a statistically significant correlation between the variables.

For this purpose, a null hypothesis is formulated as follows:

H0: There is a statistically significant relationship between vehicle price and its safety ratings.

3. Results

In 2022, approximately 192,000 new vehicles were sold in the Czech Republic, which is the lowest value since the year 2013. The reason was not limited financial possibilities of customers but rather a lack of components and logistical problems on the side of producers. A similar situation was recorded in the whole European Union, where the sales of new cars declined nearly by 5 %.

The sales figures published in 2022 show that the best-selling model was ŠKODA OCTAVIA with 13,988 new cars sold. Hyundai also ranked among the best-selling brands with the HYUNDAI I30, with 8,255 vehicles sold in the market. Other car producers, such as Volkswagen Golf, Toyota Yaris, Dacia Sandero, Toyota Proace, Kia Sportage, Toyota Corolla, Toyota RAV4, Cupra Formentor, and SEAT Arona showed lower sales, with the SEAT Arona occupying the nineteenth position (1,955 sold vehicles). Sales of individual vehicles are presented in Table 1.

The prices of the above vehicles are in different price categories depending on the model and make. For example, ŠKODA FABIA and DACIA SANDERO are affordable to a wider range of customers, with their prices being around CZK 370,000, while more luxurious models, such as TOYOTA RAV4 or ŠKODA SUPERB reach higher price levels exceeding CZK 1,000,000 due to the combination of higher-level equipment, more efficient design, and use of more advanced technologies, which is associated with higher vehicle safety.

Table 1 Ten best-selling vehicle models in 2022. Source: authors according to (Ministry of Transport, 2023)

Make / model	2022 Sales	Price
ŠKODA OCTAVIA	13988	783,900 CZK
ŠKODA FABIA	13275	369,900 CZK
HYUNDAI I30	8255	389,990 CZK
ŠKODA KAROQ	8005	675,352 CZK
ŠKODA KAMIQ	6926	479,900 CZK
ŠKODA SCALA	6529	459,900 CZK
ŠKODA SUPERB	6467	880,900 CZK
HYUNDAI SANTA FE	5817	1,150,000 CZK
ŠKODA KODIAQ	5753	1,069,900 CZK

Table 2 shows the safety ratings of the best-selling cars, which provide an important insight into the level of safety of these types of cars.

Table 2 Safety ratings of best-selling models. Source: authors according to (EuroNCAP, 2023) [34]

Model / Make	Driver safety	Passenger safety	Pedestrian safety	Active/passive safety features
ŠKODA OCTAVIA	92	83	46	55
ŠKODA FABIA	81	81	69	68
HYUNDAI I30	88	84	64	68
ŠKODA KAROQ	93	79	73	58
ŠKODA KAMIQ	96	85	80	76
ŠKODA SCALA	97	87	81	76
ŠKODA SUPERB	86	86	71	76
HYUNDAI SANTA FE	94	88	67	76
ŠKODA KODIAQ	92	77	71	54
DACIA DUSTER	71	66	56	37

As for positives, the authors point to the excellent performance of some vehicle types., specifically models such as ŠKODA KAMIQ and ŠKODA SCALA.

Table 3 Average value of one safety feature for each vehicle category. Source: Authors according to (EuroNCAP, 2023 [34] and the Ministry of Transport, 2023)

Driver safety	Passenger safety	Pedestrian safety	Active / Passive safety features
12,790 CZK	13,714 CZK	16,017 CZK	17,367 CZK

Table 3 contains information about the average costs of gaining one safety point in various categories of new vehicles. This comparison implies that the costs of safety can vary significantly in various aspects. The average value of driver safety is 12,790 CZK / point, while the safety of passengers requires 13,714 CZK per point on average. Pedestrian safety represents the highest cost, with the average value being 16,017 CZK per point. Active and passive safety features show the highest costs per point, specifically 17,367 CZK.

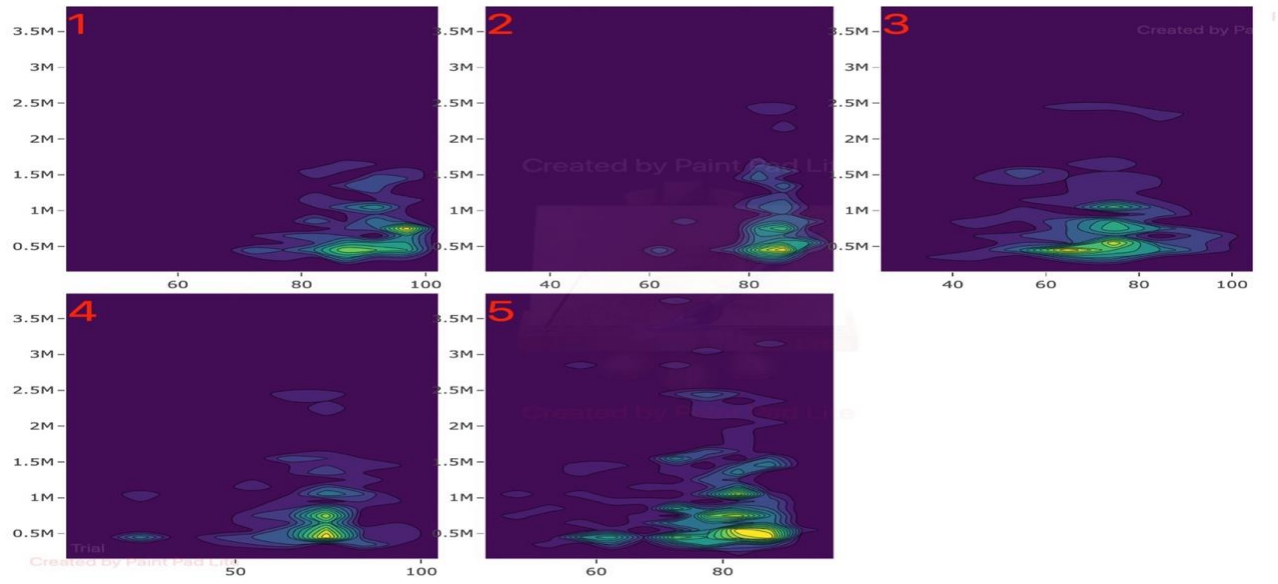

Fig. 1 Cluster analysis of the relationship between a vehicle and its price in millions of CZK. Source: authors

Figure 1 shows a cluster analysis and the relationship between a vehicle's price and distinct safety features. This visualization is divided into five clusters, each representing a unique relationship. The first cluster describes the correlation between a vehicle's price and its impact on driver safety, while the second cluster shows the association between price and passenger safety. The third cluster displays the link between vehicle cost and pedestrian safety measures. The fourth cluster shows the relationship between the price of a vehicle and its active or passive safety features. Finally, the fifth cluster presents the connection between a vehicle's price and the average value of its safety features. This analysis considers vehicle prices ranging from CZK 250,000 to nearly CZK 4,000,000, offering insights into the differentiated relationship between pricing and safety features within vehicles.

Table 4 Calculated correlation of vehicle price and driver safety. Source: authors

Method of calculating correlation	Resulting correlation	p-value
Pearson correlation coefficient	0.0125543	0.8702
Kendall's Tau	0.02336825	0.6558
Spearman correlation coefficient	0.03499516	0.6486

Table 4 shows that there is no relationship between vehicle price and driver safety scores as the resulting p-value for the statistical significance does not exceed 0.05.

Table 5 Calculation of correlation between vehicle price and passenger safety. Source: authors

Method of calculating correlation	Resulting correlation	p-value
Pearson correlation coefficient	-0.004812243	0.95
Kendall's Tau	-0.01342724	0.7997
Spearman correlation coefficient	-0.02094015	0.7851

As seen in Table 5, there is no relationship between vehicle price and passenger safety score since the resulting p-value for the statistical significance does not exceed 0.05.

Table 6 Calculated correlation between vehicle price and pedestrian safety. Source: authors

Method of calculating correlation	Resulting correlation	p-value
Pearson correlation coefficient	0.05469853	0.4761
Kendall's Tau	0.03646574	0.484
Spearman correlation coefficient	0.05596278	0.4659

Table 6 shows that there is no relationship between vehicle price and pedestrian safety score since the resulting p-value for the statistical significance does not exceed 0.05.

Table 7 Calculated correlation between vehicle price and active/passive safety features. Source: authors

Method of calculating correlation	Resulting correlation	p-value
Pearson correlation coefficient	-0.006085551	0.9368
Kendall's Tau	0.01118757	0.83
Spearman correlation coefficient	0.01382475	0.8572

Table 7 indicates there is no relationship between a vehicle´s price and the evaluation of its active/passive safety features since the resulting value of the statistical significance p-value does not exceed 0.05.

Table 8 Calculate correlation between a vehicle´s price and average score of all safety features. Source: authors

Method of calculating correlation	Resulting correlation	p-value
Pearson correlation coefficient	0.04580519	0.5507
Kendall's Tau	-0.003351969	0.9483
Spearman correlation coefficient	-0.00355175	0.9631

It follows from Table 8 that there is no relationship between vehicle price and the average score of all safety features of the given vehicle since the resulting p-value for the statistical significance does not exceed 0.05.

Since neither calculation confirmed the existence of a relationship between vehicle price and its safety ratings, the null hypothesis stating that there is a statistically significant relationship between vehicle price and its safety ratings needs to be rejected due to the inconclusiveness of the indicators.

4. Discussion

RQ1: Which new vehicles were registered in 2022 in the Czech Republic and what is their usual price?

The price of individual vehicles was influenced by various factors, including the model and make, equipment, technological features, dimensions, performance, and other factors. The price range starts with vehicles priced around 300,000 CZK available to a wider range of customers. These vehicles often belonged to the compact class and represent could be an ideal option for customers looking for a reliable and relatively cheap means of transport, such as ŠKODA FABIA, DACIA

SANDERO, PEUGEOT 108, etc. At the other end of the price range, there were vehicles with prices exceeding CZK 1 million. These vehicles often offer advanced technological features. A significant increase in interest in electric vehicles. Electric vehicles are thus becoming an increasingly attractive option for customers who want to contribute to environmental protection and at the same time, use modern technologies and innovations. The same conclusions were made by [32]. *RQ2: What is the safety rating of newly registered vehicles in the Czech Republic in 2022?*

Safety ratings are an important aspect influencing customers´ purchasing decision and choice of cars. As seen in Table 2, some models achieve excellent results in various safety aspects, for example, some best-selling vehicles, ŠKODA KAMIQ, ŠKODA SCALA, and TOYOTA COROLLA, achieve high ratings in terms of driver, passenger, and pedestrian safety, as well as in terms of active and passive safety features. The vehicle with the highest rating turned out to be AUDI A5, thus confirming the finding of [33], who argue that vehicles with higher prices achieve higher safety ratings. The same conclusion was made by [33], who confirmed that the best 20 vehicles in terms of safety ratings are those in the higher price ranges.

RQ3: What is the average value of one safety feature of these vehicles and does vehicle price influence its safety rating?

The costs of safety can vary significantly depending on individual aspects and features. The cost of one safety point increase in driver safety achieves 12,790 CZK, while in the case of passenger safety, it is on average 13,714 CZK per point. The highest average financial costs were recorded in the case of active and passive safety features (17,367 CZK per point), which is again in line with the claim of [25] as smarter technologies represent a higher financial burden. Based on the results presented in the tables, a clear conclusion can be drawn: There is no statistically significant relationship between vehicle price and its safety rating. This is confirmed by the calculation of the correlation coefficient with the corresponding p-values. In the data set, there is no sufficient statistical evidence supporting the statement that vehicle price is strongly related to its safety ratings. It is thus not possible to refute claims of by [33] who argue that more expensive vehicles achieve higher safety ratings; however, the existence of a statistical relationship between these aspects cannot be confirmed, either. This can be due to the fact that producers are increasingly trying to introduce advanced technologies and innovative designs to improve the safety of drivers, passengers, and pedestrians. As a result, even lower mid-range or lower-end vehicles can achieve high safety ratings at affordable prices.

5. Conclusion

The objective of the paper was to determine the relationship between the price of a vehicle and its safety ratings in the Czech Republic for vehicles sold and newly registered in 2022. Within the present research, the authors answered formulated research questions and rejected the null hypothesis concerning vehicle safety. The objective of the paper was thus achieved.

Vehicle sales in the Czech market are specific because the Czech Republic is known for its long-standing automotive manufacturing base. The Czech Republic is home to ŠKODA, which has the largest share in the sales of new and used vehicles.

Ensuring safety on the roads remains a priority for the automotive industry, which encompasses the efforts to minimize the number of injuries and fatal accidents, and to create a safe environment for users. The cost of ensuring safety is not constant and can vary depending on the specific technologies and innovations implemented in vehicles. This factor is an important aspect, which, however, does not affect the final price of the vehicle on the market. The results of the research are statistical calculations, which confirm that there is no relationship between vehicle price and its safety rating. It can thus be stated that although safety plays an important role in the design and manufacturing of new vehicles, the price of the vehicle is not a decisive factor in achieving higher ratings. These findings can be of importance for consumers and the automotive industry as they provide specific information on the relationship of these two key vehicle characteristics.

Vehicle price can be influenced by various factors, many of which may not be directly related to safety, such as vehicle make, equipment, technology innovations, design, and other aesthetic features. This means that the automotive industry can offer other vehicle types with various safety ratings for various prices without the price difference depending on the level of vehicle safety.

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