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Assessment of luggage compartment parameters based on the preferences of a heterogeneous driver group

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Abstract. This work deals with the assessment of driver preferences in the area of passenger car luggage compartments. The data collected is compared to that of real vehicles from the full range of passenger cars available on the European market. The data used for the research described in this work was obtained using a questionnaire survey on a large heterogeneous group of drivers in the Czech Republic. All of the research participants had three categories of vehicles available during testing - for better imagination and the possibility of personal comparison of parameters. The collected data was subsequently subjected to statistical evaluation, where mainly statistically significant dependencies in the preferences of individual drivers were sought out given their personal and anthropometric parameters. On the basis of the statistical evaluation of the obtained data, a difference was found in the preferences of the types and dimensions of the individual luggage compartments for the individual respondents depending on the selected parameters. The results of this work can be used in the process of designing luggage compartments of passenger cars, in particular with regard to the specific needs of drivers. The results of the work could thus contribute to improving the safety in handling cargo in the luggage compartments of vehicles and to improving health protection.

Key words: driver, luggage space, vehicle, gender, age.

INTRODUCTION

Nowadays, passenger car ergonomics are considered to be an increasingly important part of the car design process (Wang et al., 2007). An optimally ergonomically designed luggage compartment is of the same importance as, for example, the driver's workplace and plays a large role both in terms of the safety of the person who uses the luggage compartment, and in terms of the complete vehicle crew (Reed, 1998). The luggage compartment of a modern passenger car is the part of the car that is used practically constantly during the use of a passenger car, not only by the driver but also by other persons using the vehicle (Bhise, 2012). However, the person who decides on the parameters of a newly purchased car intended for personal use is usually the person who will most often use and drive it. Therefore, when determining the luggage compartment motivation and preference, it is necessary to use a test group as a reference, in particular drivers. The basic dimensions of the luggage compartments of modern passenger cars are generally determined primarily according to the type of vehicle, its determination and its basic external dimensions. Nevertheless, during design processes,

the dimensions of the luggage compartments can be influenced to a certain extent to achieve optimization in order to increase the utility value and optimize the ergonomic parameters of the luggage compartment. The degree of optimization and adaptation of the luggage compartment to the driver's requirements can thus directly influence not only the vehicle's utility value, but also the driver's feelings and overall comfort, and thus also the safety of the vehicle (Matoušek, 1998; Reed, 1998; Hruška 2016). For example, this concerns the driver's motivation process to make better use of the luggage compartment to store cargo, instead of placing cargo in other areas of the vehicle's cabin where it could pose a potential safety risk (Tilley, 2002; Vágnerová, 2007).

The volume of the luggage compartment in litters (dm^3) is now commonly used as a reference value for comparing luggage cars. However, this value is inadequate in terms of practical use in ergonomics because it does not take into account the basic geometric arrangement of the luggage compartment. With respect to the operator's health, in particular the length (sometimes also referred to as depth) of the luggage compartment is a key value when handling cargo. For optimal handling of cargo in the entire luggage compartment area, it is necessary to combine two basic movements, which are very complicated in terms of human biomechanics because several muscle groups are involved in them at once (Haug et al., 2004). The basic movement is the (forward bend) anteflexion of the thoracic and lumbar spine, and the secondary movement is the stretching of one or both arms forward, depending on the weight and shape of the load (Véle, 1995; Havlíčková, 1999). The load rate of muscle groups is determined by several factors, and if we ignore the shape and weight of the load, the main factor is the geometric shape of the luggage compartment and the anthropometric data of the driver.

The primary goal of this work is to find out if there is any dependency between the measured parameters of drivers and their preferences in the luggage compartment area. The secondary goal of this work was to find out what luggage compartment dimensions the drivers of the selected test group prefer and whether there is any dependency between the preferred luggage compartment dimensions and the parameters of a specific driver.

MATERIALS AND METHODS

Participants

For the purposes of measurement, 140 participants (72 women and 68 men) from the Czech Republic were obtained, all of whom are in the university environment – students or teachers of technical or economic orientation. The age of the participants ranged from 19 to 67 years (the average age was 34 years). It was unambiguously required and verified that all of the participants were to have a driver's license enabling them to drive passenger cars. All of the participants were also in good health and had no restrictions on the musculoskeletal system.

Table 1. Number of persons tested and their primary parameters in relation to measurement

	Number	Age (number in age group)			Partner relationship	
		18–25	25–35	35+	single	In a relationship
Men	68	18	29	21	19	49
Women	72	6	22	44	14	58
Total	140	24	51	65	33	107

In addition to their age and gender, each tested subject also specified their marital status (single or in a relationship) and stated which car they most commonly used at the time of measurement. The most commonly used vehicle was then assigned to one of the pre-selected categories, as shown in Table 2. Body height was also measured for each subject when wearing normal walking shoes. All of the testing was done anonymously and according to the principles for work with personal data.

Table 2. Number of tested persons and their secondary parameters in relation to measurement

	Number	Height (number)			Vehicle that they primarily drive		
		Up to 172	172–180	over 180	small	medium	large
Men	68	3	22	43	13	35	19
Women	72	45	26	1	25	34	13
Total	140	48	48	44	38	69	32

*Note: Small hatchbacks and mini-cars were classified in the **small** vehicle category. Medium limousines and a small SUVs were included in the vehicle group designated as **medium**. Limousines, large sedans and large SUVs were included in the **large** vehicle group.*

Test environment

Testing was conducted under laboratory conditions with uniform illumination and a working temperature of 20 °C. The tested individuals were provided with the comparative vehicles specified in Table 3. The luggage compartment dimensions of the comparative vehicles specified in Table 2 were taken from the official sources of the manufacturers and subsequently additionally checked using a laser rangefinder prior to testing. Each person tested also had a manual measuring meter in the metric system, so that everyone could check the dimensions of each luggage compartment. Roughly 20 percent of the tested persons did not trust some of the specified luggage compartment dimensions, and therefore took advantage of the opportunity to measure specific dimensions. At the time of measurement, all of the vehicles had open luggage compartments with doors in maximum position and the luggage compartments were empty and without any additional adjustments.

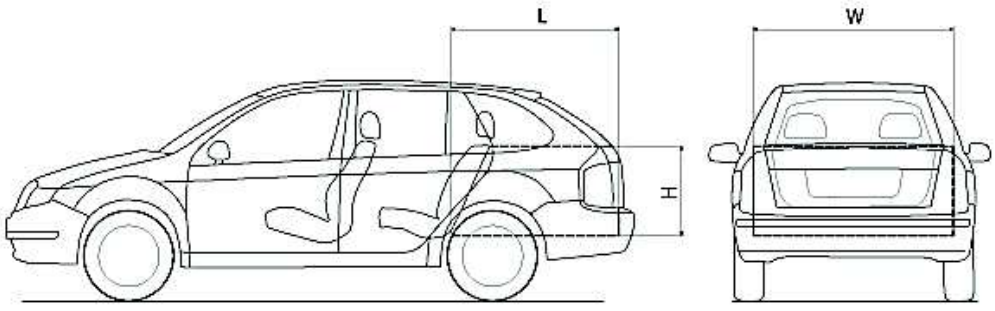

Figure 1. Position ranges of seat and steering wheel in the test vehicles.

Data Collection Procedures

Each person tested had a trained assistant available who recorded their responses. First, each tested subject carefully inspected, and possibly measured all of the comparative vehicles and then answered the questions asked. After asking the question,

the test person's assistant always asked if he or she understood the question and whether he or she needed to add or explain something. If the person tested was not sure about a question, the assistant always explained the question so that the baseline information level of all of the tested persons was adequately balanced. There was no time limit set for answering the questions, and therefore each tested subject had enough time to think about their answers.

Table 3. Basic dimensions of luggage compartments of comparative vehicles

Type of vehicle	Length (L) (cm)	Height (H) (cm)	Width (W) (cm)	Volume (dm^3)
Škoda Fabia Combi 2018	96	60	95	530
Škoda Octavia Combi 2016	105	63	101	610
Škoda Superb Combi 2015	114	65	101	660
Škoda Yeti 2013	80	72	103	405 [1)]
Škoda Kodiaq 2016	116	74	100	650 [1)]
Ford Mondeo Combi 2013	118	42	114	554

Note: The length, height and width dimensions were verified as part of testing on specific test models. The luggage compartment volume values were measured according to standard VDA V210-2 and were taken from the official databases of the manufacturers. 1) The lowest luggage compartment volume value is used.

The test subjects were asked a total of 10 questions divided into three basic groups. The first group consisted of questions identifying the drivers' preferences in terms of the luggage compartment when buying a new vehicle. The second group of questions concerned how the luggage compartment was used. The last group of questions examined what luggage compartment parameters would be considered optimal by the tested drivers (Table 4).

Table 4. Questions and response variants used in clinical data collection

Question	Wording of question	Answer 1	Answer 2	Answer 3
A	What do you prefer for the LC[1)] …	Length	Width	-
B	What bottom limit for the LC do you prefer[1)]…	Even	Raised	-
C	What criterion is the LC[1)] for you when choosing a new vehicle…	Primary	Secondary	-
D	I usually place luggage on…	The floor	The seat	In the LC[1)]
E	I put cargo in the LC[1)]…	Freely	I use organizers	-
F	Load limit of the LC[1)] when handling cargo…	I use it	I do not use it	I'm afraid to encumber it
		Ranges of values		
G	In my opinion, I can encumber the load limit with a weight of about	10–25–50–75–100 kg – more		
H	In your opinion, what is the optimum width of the LC?	Up to 105 cm	105–115 cm	Over 115 cm
I	In your opinion, what is the optimum length of the LC?	Up to 100 cm	100–120 cm	Over 120 cm
J	In your opinion, what is the optimum height of the LC?	Up to 60 cm	60–70 cm	Over 70 cm

1) LC – luggage compartment.

After the measurements were completed, all of the data was digitized and evaluated using PivotTables and Pearson's chi-squared test. In order to facilitate statistical evaluation of the measured values, some quantitative results were divided equally into three groups.

RESULTS AND DISCUSSION

The results obtained during the measurements were statistically processed and evaluated using PivotTables and Pearson's chi-squared test at a significance level of 0.05. Furthermore, the adjusted residuals method was used for further refinement and better interpretation of the found dependencies. The tables below show only those results that were found to be dependent. There were no dependencies found for questions that are labelled B, D, and G in Table 4, and therefore these results are not shown, and they are no longer worked with.

In Table 5, which shows the results related to question A, a dependency was manifested between the width to length preference of the luggage compartment and the type of partnership relationship that the respondent is in. Using the adjusted residuals method, it can be stated that respondents who are in a relationship prefer a significantly longer length (depth) of the luggage compartment compared to width. For respondents who are not in a relationship, the width or length preference was nowhere near as strong, and in this respect, respondents from this group do not make significant differences.

Table 5. Dependence of preferred luggage compartment dimensions (question A) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	0.003	3.84	0.005	None
Partnership	8.29	3.84	0.24	Medium dependence
Primarily driven vehicle	5.05	5.99	0.19	None
Body height	0.64	5.99	0.06	None
Driver age	0.72	5.99	0.07	None

In Table 6, where the statistical results related to question C are shown, dependencies were observed for virtually all of the assessed parameters, with the exception of the parameter that takes into account the type of vehicle most frequently driven by the respondent. Using the adjusted residual method, the results can be interpreted as meaning that for women, the luggage compartment is a more important criterion that plays a role in the decision-making process when buying a new vehicle than for men. For men, this criterion tends to be considered secondary.

Table 6. Dependence of the luggage compartment as a criterion on the selection of a new vehicle (question C) on driver parameters as specified in Tables 1 and 2

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	8.36	3.84	0.24	Medium dependence
Partnership	10.89	3.84	0.27	Strong dependence
Primarily driven vehicle	0.95	5.99	0.08	None
Body height	12.71	5.99	0.30	Strong dependence
Driver age	13.41	5.99	0.31	Strong dependence

Furthermore, it can be stated that for respondents who are in a relationship, the luggage compartment is a significantly more important decision parameter than for respondents who are not in a relationship. This parameter is also very significant for smaller respondents and for older respondents. Conversely, younger respondents mostly consider this a secondary parameter.

In Table 7, where the results relating to question E are presented, only a single, strong statistical dependency emerged between the way in which the respondent arranges cargo in the luggage compartment and the respondent's gender. Using the adjusted residual method, it can be stated that men more often deposit cargo in a luggage compartment in a disorderly manner, whilst women much more often use a variety of organizers for attaching cargo. Dependencies on other parameters were not manifested in this case.

Table 7. Dependence of organizing a load in the luggage compartment (question E) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	12.07	3.84	0.29	Strong dependence
Partnership	2.19	3.84	0.12	None
Primarily driven vehicle	0.95	5.99	0.08	None
Body height	3.01	5.99	0.14	None
Driver age	4.64	5.99	0.18	None

In Table 8, where the results relating to question F are presented, dependencies were manifested between the use of the lower load limit of the luggage compartment and the gender and age of the respondent. Using the adjusted residuals method, it can be stated that men use the load limit more than women. Furthermore, it can also be claimed that younger respondents are very often afraid to use the load limit for fear of damaging the vehicle. This finding can be considered surprising and can only be explained by a lower level of general technical knowledge and awareness of the structure of a passenger car in the younger population of respondents.

Table 8. Dependence of the load limit of a luggage compartment (question F) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	11.23	5.99	0.29	Strong dependence
Partnership	3.49	5.99	0.16	None
Primarily driven vehicle	7.52	9.48	0.17	None
Body height	7.91	9.48	0.14	None
Driver age	15.33	9.48	0.24	Medium dependence

In Table 9, where the results relating to question H are presented, only a weak statistical dependence was manifested among the preferred optimal luggage compartment width and the type of vehicle that the respondent most often drives. Using the adjusted residuals method, it can be stated that respondents who are currently driving in small cars prefer a small luggage compartment width. These findings could be interpreted as a coincidence of the compliance of preferences of drivers who have chosen a small vehicle, are satisfied with it, and hence do not wish for a wider luggage

compartment. Other dependencies could not be proven. Overall, however, all of the respondents cited the optimum luggage compartment width size of an average of 5–10 cm wider than the average width of luggage compartments of models commonly available on the European market (Table 3).

Table 9. Dependence of the preferred width of the luggage compartment (question H) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	1.08	5.99	0.08	None
Partnership	4.04	5.99	0.17	None
Primarily driven vehicle	9.97	9.48	0.19	Weak dependence
Body height	2.08	9.48	0.08	None
Driver age	1.47.	9.48	0.07	None

In Table 10, where the results relating to question I are presented, dependencies were manifested in the preferred optimum length (depth) of the luggage compartment and the type of respondents' relationship, as well as the type of vehicle the respondent most often drives. Using the adjusted residuals methods, it can be stated that single respondents are much more satisfied with short luggage space, while respondents in a relationship prefer medium and longer luggage compartments. Furthermore, it can be claimed that the luggage compartment length preference of the respondents accurately reproduces the type of vehicle that the respondents are used to driving. Respondents who use large vehicles prefer a long luggage compartment, while respondents with small cars prefer a shorter luggage compartment. This can be interpreted in a similar way to Question H, where there is a clear correlation between respondent preferences and the vehicle types they use.

Table 10. Dependence of the preferred length of the luggage compartment (question I) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	1.29	5.99	0.09	None
Partnership	8.33	5.99	0.24	Medium dependence
Primarily driven vehicle	14.34	9.48	0.22	Medium dependence
Body height	5.36	9.48	0.13	None
Driver age	7.45	9.48	0.16	None

Table 11. Dependence of the preferred height of the luggage compartment (question J) on driver parameters as specified in Tables 1 and 2.

Driver parameter	X^2	Critical value	Cramer V	Dependence
Gender	8.50	5.99	0.24	Medium dependence
Partnership	2.52	5.99	0.13	None
Primarily driven vehicle	10.86	9.48	0.19	Weak dependence
Body height	9.60	9.48	0.19	Weak dependence
Driver age	7.84	9.48	0.16	None

In Table 11, where the statistical results relating to question J are presented, dependencies were manifested in the preferences of the height of the luggage compartment on the gender of the respondent, the type of vehicle that the respondent

most often drives and the height of the respondent. Using the adjusted residuals method, the results can be interpreted in such a way that women prefer a higher luggage compartment, while men prefer a lower height. Even with this question, it can be stated that drivers who drive small vehicles also prefer a lower luggage compartment. For drivers of other types of vehicles, the dependencies are not as obvious. Furthermore, it can be stated that respondents of medium height most often prefer low luggage compartments, whilst shorter respondents prefer high luggage compartments. Here, above all, we can see the strong influence of the factor of the tested women, who are naturally smaller, and who prefer high luggage compartments, as described above. Both of these findings correlate well with each other.

CONCLUSIONS

In this work we managed to obtain a large number of valuable primary data from a relatively homogeneous group of respondents, which may be statistically interesting in terms of possible comparisons with other statistics obtained from respondents with different parameters, such as different education, nationality, cultural habits, etc. By dividing the data using PivotTables and using the adjusted residuals method, it was found that statistically significant dependencies can be found between the preferences of the interviewed drivers with regard to the luggage compartments of passenger cars and their anthropometric and sociological parameters.

Based on the above results, it can be stated that the existence of a dependency between anthropometric and sociological parameters of the tested subjects and parameters related to the working area of the luggage compartments of passenger cars was proven. It should be noted, however, that the number of found dependencies is relatively small and manifests itself especially where the dependence on gender or the possible existence of a respondent's partnership relationship is evaluated. Parameters such as age or body height of respondents do not play almost any, or only a minimal role in the sought out dependencies. These parameters play an exceptional role only in some sought out dependencies, such as the significance of the luggage compartment in the decision-making process during the purchase of a new passenger car.

The ascertained results could be used in passenger car development processes and the subsequent optimization of their luggage compartments to better suit users' needs. For example, according to their preferences, all of the respondents would appreciate wider luggage compartments, regardless of the particular category of passenger car. It can also be stated that for a statistically significant group of respondents, the luggage compartment and its processing and parameters are an important factor in the decision-making process when buying a new passenger car. This criterion is particularly important for women and for respondents who are in a relationship. Another interesting result was the assessment of the dependency of organizing cargo in the luggage compartment on the gender of the respondent, where it was clearly demonstrated that women are more responsible in this respect and, in significantly more cases, they use different types of organizers to arrange and secure cargo in the luggage compartment of a passenger car.

The results presented in this work could serve as a basis for further research to further refine the above findings. The data and hypotheses presented in this paper could serve as ancillary factors in the car design process with regard to potential customer target groups.

The development of passenger cars always moving forward, and the parameters of vehicles and their luggage compartments are constantly evolving and changing to better meet the demands of vehicle users. It can be claimed that the results described in this work can further improve the understanding of luggage compartment optimization of a passenger car, in particular with regard to the requirements of drivers, customers or, in general, passenger car users.

No references are given for the above conclusions because no comparable studies are currently available.

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