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Automotive Ergonomics: Passenger Cars Interior Dimension Parameters and Comfort

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Abstract— Automotive ergonomics is the study of how automotive can be designed better for human use. The human factor aspect of designing automobiles is first considered at the Vehicle Packaging stage. The term Vehicle Packaging comes to use whenever a new model is in the early stage of study. It is a method to safeguard and protect space for the human user and necessary components that make up the vehicle being designed. Other purposes are to provide alternative solutions and proposals, to ensure the legal requirements are met and to ensure all in-house requirements are met. This study is to correlate automobiles interior dimensions to comfort factors by means of measuring and survey as well as using ergonomic software. Four cars are compared to achieve this objective. From the result, it can be seen that dimension factors of interior affects the car ergonomic factors. By looking into specific dimension parameters, one can see the differentiation between all four cars. For driver's comfort as well as reach factors, survey shows majority respondents prefer Honda City and Toyota Vios. However from discomfort assessment using Ramsis, it was suggested that both Proton cars gives better comfort for taller population while Honda City and Toyota Vios gives better comfort for shorter population. Other factors evaluated were driver clearance and spaciousness, driver seat and steering adjustability, driver reach ability to surrounding components, driver view (inside and outside), front and rear door entry / exit, rear passenger spaciousness and view, vibration and noise, and trunk space.

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I. Introduction

Vehicle Packaging in short is the organization of space for people and the parts of a vehicle to suite a specific need or transport. It is the first consideration for shaping the vehicle. At Vehicle Package stage, factors such as engine size, weight, width, height, luggage, number of passengers and their seating arrangement are targeted. Knowing all the said parameters plus more will help to establish a range of dimension within a category of vehicle types and cost, enabling the designer to target the shape of vehicle on a "family of dimensions" that will make it competitive.

Vehicle Packaging actually dictates of how a vehicle should be designed. It provides all the necessary information for the styling designers and part designers to proceed with at the following stage. Without vehicle packaging input, all the design engineers will not be able to proceed with the design concept in details. On the other hand, since Vehicle Packaging is meant to provide suitable space for people and parts in vehicle, human factor consideration is a must for the integration of the total design. In vehicle design, the term human factor is interchangeably called as automotive ergonomics [1].

In designing an automobile, there have to be certain dimensions that have been agreed for by the management, design, and manufacturing departments. As much as design attractiveness is important, so do the cost factor and manufacturing capability. Design has to be aligned with proper product positioning and budget as well as manufacturing line setup. To make sure all these factors merged in, vehicle packaging takes all this factors in drafting the total layout of the automobile. Ideally, a perfectly packaged automobile will definitely determine the number of sales. One must not misconstrue vehicle packaging as the total deciding factor for sales. Instead, Vehicle Packaging is the starting point of an automobile design processes. Other major sales factor such as quality of components relates to later stage of design where it deals with a lot of other factors which is outside the scope of this paper.

The vehicle packaging setup for different makes varies. Comparing with the same segment car such as medium sedan, one can see the differences such as seating arrangement and steering height. In terms of knowledge, one will have vague idea of how certain dimensions were decided for different makes since all manufacturers have their own guidelines. How and why the dimensions were opted is unknown to people outside the automotive design circles. Even so, production cars can be studied and measured to get the Vehicle Packaging specifications.

II. METHOD

In order to meet the objective, four passenger cars are selected to be measured in order to investigate for the dimension parameters that contributed to automotive ergonomics consideration. Cars selected are Toyota Vios, Honda City, Proton Gen2 and Proton Waja. Car user input will be taken into account from questionnaires that are intended to seek customer's preference. Through dimension measurement and CAD data, general packaging parameters for passenger cars will be analyzed. Seating comfort level of all said cars will be evaluated and discussed Virtual comfort measurement will be made to use for comfort and clearance study to 95% men and 5% women populations [11]. The end result will report on the findings from survey, measurement, and analysis.

III. SURVEY QUESTIONNAIRES

From the survey result, the answers are divided into 5 categories from scale 1 to 5 which consist of poor, meets requirement, acceptable, commendable, and outstanding. Each car was evaluated by 21 respondents. The survey was meant to get the general idea of satisfaction for each car driver. Only general questions could be asked to make it easier for them to answer all questions. Mean of respondents' rating are calculated and put in table 1.

Table 1 Questionnaires scores

Survey Subject / Car	Gen2	Waja	City	Vios
Comfort of seating in driving position	3.1	3.0	4.0	3.9
Comfort in reaching to use all the features & major switches	3.4	3.2	4.0	4.0
Comfort & spaciousness in seating on all other seats	2.8	3.3	4.3	3.0
View to meters & readability of all the important gauges	3.6	3.2	3.8	3.8
View outward front, rear, side and rear quarter / blind spot	2.6	2.8	3.5	3.1
View for all passengers front and rear / claustrophobic level	2.8	3.0	3.5	3.7
Trunk room space and opening width, lip height and depth	3.6	3.2	4.6	3.6
Entry and Exit Fr	3.4	3.4	4.0	4.0
Entry and Exit Rr	3.0	3.0	3.8	3.6
Driver Seat Adjustability	3.0	2.8	4.0	3.5
Steering Wheel adjustability	3.0	2.8	4.0	3.5
Noise Suppression level	2.4	2.5	3.5	3.1
Vibration and Harshness level	2.6	2.7	3.6	3.3

IV. DIGITAL MEASUREMENT

To assess the interior of each car, SAE size manikin is placed in the digitized car model. A cad tool (Catia) is used to measure the digitized data. SAE manikin is a 2-D drawing of 95% tile American/Canada population which is used as standard in setting up driver's position layout [8]. The manikin hip point is placed so that it coincides with the seating reference point that has been determined earlier by means of physical measurement with a H-Point machine [9]. Car layout is constructed using hundreds of digitized points from Coordinate Measuring Machine (CMM). Points are refined in Catia V5 as shown in figure 1.

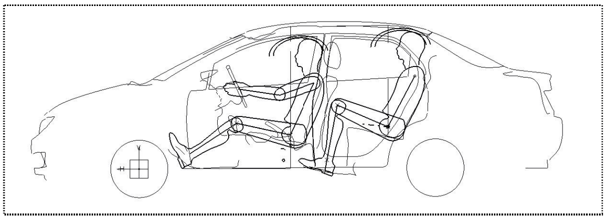

Figure 1 Scan data

Specific for the driver seating position, dimensions A, B, and C as shown next are measured. For adjustable range such as A values and C values, comfort level varies for different people size, therefore the only value that is independent of people size for study cars is seating height. Reason being seating height adjustment is not equipped for these cars. So driver will just have to make use of seat back tilt and seat cushion horizontal adjustment for comfort [3]. For the back angle, standard setting position for H-Point machine is 25 degrees for front occupant [10]. Dimensions were measured and put in table 2; figure 2 shows the dimensions measured graphically.

Table 2 Rear most position for driver seat

Car / Dimension(mm)	A	B	C
Honda City	899	275	25
Proton Gen2	950	265	25
Proton Waja	960	264	25
Toyota Vios	917	264	25

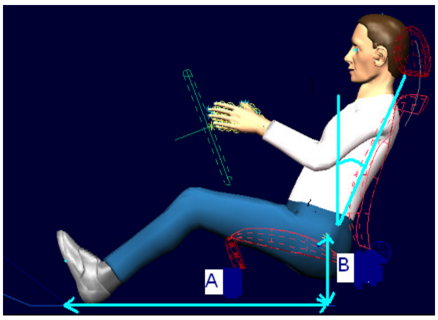

Figure 2 Driver position dimension

V. ERGONOMIC SOFTWARE ANALYSIS

(a) Comfort rating

A vehicle ergonomic software (Ramsis) will be used to evaluate seating position for all four cars. The evaluation will find a level of discomfort at specified seating position. So the value of less discomfort is preferred. The inputs for the software to evaluate the driver position will be SgRP (Seating Reference Point), Pedal point, and Steering point. The back angle will be according to optimal angle as calculated by Ramsis. Based on the digitized hard points, three positions of driver seating are analyzed:

i) At Design Position (using 95%tile manikin of USA/Canada)
ii) At Best Position (using 95%tile manikin of USA/Canada)
iii) At Best Position (using 5%tile manikin of Japanese/Korea/Malaysia)

Table 3 Comfort score

Seating Position \ Car	Proton Waja	Proton Gen2	Honda City	Toyota Vios
At SgRP	3.4	3.4	3.7	3.8
At optimal for 95%tile	3.3	3.3	3.5	3.8
At optimal for 5%tile	4.2	4.2	3.9	4.0

(b) Interior dimensions

Apart from comfort evaluation, factors such as clearance, reach, and view field are measured. Such measures are taken by using 3D manikin [2]. Car geometries that are related to human factor are also measured such as seat and steering travel range as well as door dimensions.

Table 4 Clearance to surrounding

Clearance to (mm) \ Car	Proton Waja	Proton Gen2	Honda City	Toyota Vios
Headlining	68	60	59	67
Door Trim	51	49	39	56
SgRP – Steering Horizontal Distance	442	432	438	448

Table 5 Steering and seat allowance

Car	Proton Waja	Proton Gen2	Honda City	Toyota Vios
Steering Adjustable Vertical Range (mm)	40	40	50	35
Horizontal Seat Range (mm)	250	240	245	243

Table 6 Reach to component

Car \ Reach	Gear Shift	Instrument Panel Switches (reach distance)	Power Window Switches & Door Inside Handle
Proton Waja	105 mm inside envelope	56 mm	Within envelope
Proton Gen2	68 mm inside envelope	36 mm	Within envelope
Honda City	70 mm inside envelope	56 mm	Within envelope
Toyota Vios	70 mm inside envelope	35 mm	Within envelope

Table 7 Vision angle

Car	Proton Waja	Proton Gen2	Honda City	Toyota Vios
Front View Field Angle	26 °	23.2 °	19.5 °	25.6 °
Rear View Field Angle	6.2 °	3.8 °	5.6 °	5.3 °
Total Pillar Obscuration Percentage	12.6 %	14.6 %	15.5 %	18.9 %

Table 8 Door allowance

Car \ Criteria	Fr Dr Entry Height (mm)	Rr Dr Entry Height (mm)	Rr Dr Exit Height (mm)
Proton Waja	830	787	772
Proton Gen2	799	806	731
Honda City	778	727	706
Toyota Vios	803	804	693

Table 9 Interior space

Car	Proton Waja	Proton Gen2	Honda City	Toyota Vios
Head Room (mm)	39	-10	30	15
Leg Room (mm)	785	760	812	773

VI. RESULT ANALYSIS

Comparing between results of survey and results of measurement and analysis will show the correlation between the two. Survey was taken to identify driver's perception towards the four cars in terms of aspects that are often seen in car evaluation standards. Measurements were done to identify the dimensions involved and then ergonomic software was applied to analyze the dimensions involved. However the software was only utilized to the extent of manikin analysis. Those physical aspects of car structure were concluded by the survey questionnaires.

For driver's comfort as well as reach factors, survey shows majority respondents prefer Honda City and Toyota Vios. Since the survey does not take into account the anthropometrics of respondents, it cannot tell in terms of people size that gives such answer. However from discomfort assessment using Ramsis, it was suggested that both Proton cars gives better comfort for taller population while Honda City and Toyota Vios gives better comfort for shorter population. From the fact that all respondents are Malaysians, it is convincing that the seating position of Honda City and Toyota Vios is suiting more towards the lower range of stature.

From survey, rear occupant's comfort is favored to Honda City, followed by Proton Waja. While Toyota Vios and Proton Gen2 were rated less favorable. Discomfort assessment was not done for rear occupants since their foot location cannot be ascertained for sure, therefore measurement analysis was done to rear space by taking into account the rear legroom and rear headroom. Proton Waja and Honda City has a larger legroom compared to Toyota Vios and Proton Gen2. The same correlation also applicable to head room as the dimension of Honda City and Proton Waja is clearly bigger.

In terms of reach, Proton Gen2 and Toyota Vios have smaller instrument panel reach distance than Proton Waja and Honda City. Thus, Thus Proton Gen2 and Toyota Vios have better reach distance to instrument panel than the other two. For clearance factor, clearance to door trim, headlining and steering was measured. Proton Waja and Toyota Vios have the largest clearance from driver’s head to headlining. Although Honda City’s value is the lowest, it is still considered acceptable. Clearance to the nearest surface of door trim and clearance to steering wheel center, Toyota Vios tops while Proton Waja and Proton Gen2 are marginally lower and Honda City’s is the lowest.

Outward vision factors were determined by measuring front and lower field vision as well as pillar obscuration. Honda City was preferred by respondents in terms of that and both Proton cars were less favored. The results of measurement varies where the lower vision for Honda City and Toyota Vios is better while Proton Waja wins in terms of overall field angle and Proton Gen2 mainly losing for its rear vision. From measurement, Proton Waja has the smallest percentage of pillar obscuration and therefore better than Toyota Vios which ranks the last for its large C-pillar without quarter glass. For inside vision, Honda City was preferred and Proton Waja is last according to respondents. Using Ramsis, differentiation cannot be made for certain since the viewing cone actually covers all the important location on instrument panel for all four cars.

For entry/exit factor from respondents, Honda and Toyota wins. From measurement result, Proton Waja has the best front entry / exit height while Honda City has the lowest. For rear door, Proton Gen2 has the best entry height follows by Toyota Vios, Proton Waja, and Honda City. Moving to rear exit height, Proton Waja has the biggest also while Toyota Vios has the smallest. Generally, front and rear passenger will prefer Proton Waja door openings and less to Toyota Vios. In terms of foot movement during entry / exit, Toyota Vios and Proton Waja is better for front door. Proton Waja has the best rear passenger foot entry / exit clearance while Proton Gen2 has the worst.

Seat and steering adjustability of Honda City and Toyota Vios wins according to the survey. This correlates to measurement of upper range of steering movement where both cars have in excess of 200 mm clearance to seat cushion. For front seat adjustment range, Proton Waja has the biggest value while Proton Gen2 has the smallest value. However, for all four cars the range is between 240 mm to 250 mm. From Ramsis, the most optimal adjustability range is at 240 mm. Having more than that will accommodate more than 90% of user population.

With regard to noise suppression level, Honda City if the most silence while Proton Waja is as good as Toyota Vios and Proton Gen2 is rated worst or noisier upon driving. The least vibration and harshness level is won by Honda City, follows by Toyota Vios. As shown, Honda City tops the list as the car with the highest volume of trunk. This follows by Toyota Vios and Proton cars.

VII. Conclusion

From the survey perspective, the surety of results is inconceivable since the factor of bias could have take place. People who prefer imported cars would give a better rating for all questions asked even though local cars have the better measurement result. Since some questions were not clear to respondent, the answer may as well be uncertain. Also the external factor such as time, environment may have affected their answers. Generally, quality of components could be the big factor since one who has experienced at least one part of defect in their car will actually affect their judgment towards other factors in the car. So measurement and comparison will give a better understanding of how packaging of car interior contributes to automotive ergonomics.

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