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QUESTIONNAIRE-BASED SURVEY ON DRIVERS' NOISE AND VIBRATION DISCOMFORT

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Abstract

A questionnaire-based survey was conducted to gather information regarding driving discomfort of Malaysian passengers' vehicle drivers. The discomfort factors investigated were noise and vibration in the vehicle both during idle and accelerating conditions. In the final survey, there were 63 subjects. It was found that 37% voted for engine noise during idle as compared to 32% for engine noise during accelerating. Men were found to experience less discomfort than women drivers in most of the driving conditions investigated. At the same time, age difference showed a different trend of response.
Keywords: Noise, vibration, driving, discomfort, survey, questionnaire,

1. INTRODUCTION

A survey or distribution of questionnaire is a common step in discomfort study especially in the preliminary stage[1-7]. Kolich and White[3] suggested "surveys are and will always be the best way to understand customer/consumer perceptions and expectation of comfort". Shen and Parsons[5] defined discomfort as "a generic and subjective sensation that arises when human physiological homeostasis, psychologically well-being, or both are negatively affected". There is yet a standard methodology in measuring people perceptions hence reduces the comparability of statistics developed by different researchers [1, 4].

It is undeniable that today's car is much more comfortable and has improved so much in many ways including in the noise and vibration aspects. Although noise, vibration and harshness (NVH) has been around for sometime in automotive engineering[8], it is still in its infancy stage in Malaysian automotive engineering scenario. Winter[8] gave examples of automotive companies like Nissan Motor Corp., Mazda Motor Corp. and Ford Motor Corp. which spent millions US dollars in NVH technology alone. Lexus LS400 smoothness and BMW closing-door sound are few examples of NVH benchmark.

This study focuses on Malaysian drivers. Additionally, the majority of driving discomfort surveys investigated either seat discomfort or musculoskeletal disorders as a result of driving[9-12]. Noise and vibration were asked only as one part of a total vehicle evaluation and were regarded as 'other sources of seated discomfort' [11-12]. Noise and vibration usually are investigated through subjective evaluation in laboratory environment[3, 15.] Table 1 summarizes the driving discomfort researches explored by some of the above mentioned authors.

Table 1 Summary of driving discomfort survey literatures

Authors	Scope	Method
Mansfield & Marshall (2006)	Study of symptoms of musculoskeletal disorders for rally drivers and co-drivers in UK. Number of subjects, n=13 professional and 105 amateur.	Whole body and hand/wrist symptoms loosely based on Nordic Musculoskeletal Questionnaire and UK Medical Research Council
Giacomin & Screti (2005)	Human upper body discomfort. Samples were taken in Turin, Italy with n=269 drivers. Time to complete questionnaire about 14 minutes and n for pilot study=20 drivers.	Self-administered questionnaire using Borg CR-10 scale for the main section of the questionnaire.
Giacomin & Gnanasekaran (2005)	Steering wheel vibration-intensity, Pilot study, n=20. Time to complete questionnaire about 12 minutes. Samples represent Northern of England drivers, n=350.	Borg CR-10 consists of 17 level points (9 labeled and 8 unlabelled).
Porter et al. (1992)	Car driver discomfort in UK. N=1000 drivers approached in 3 motorway service stations.	2 types of rating scales; i. 4 point discomfort scale for 20 body areas ii.overall assessment of body comfort and their seat
Schneider & Ricci (1989)	Seating discomfort and related factors (body region) for n=142 who reported no discomfort and n=110 who reported even a slight discomfort	Investigator administered questionnaire/interviews. Different set of questionnaires for drivers who reported no discomfort and who reported discomfort.

The basic types of measurement scale consist of nominal, ordinal, interval and ratio. Nominal scale is used when a respondent is asked to classify himself according to gender, age and the like. Ordinal is when a respondent is asked to rank order their preferences. Interval or also known as Likert response scales are like the 3-point scales and 5-point scales. Ratio scale demands respondent to report a numerical value in ratio of the value of the standard stimulus. Smith et al.[1] developed a survey tool named Automotive Survey Discomfort Questionnaire (ASDQ). It was suggested that discomfort is continuous hence it is more appropriate to use a continuous scale like the visual analog scale rather than scales with intermediate anchors like the Likert scale. Nevertheless they still acknowledge the significance of surveys done by Kolich and Taboun[14] (where most questions were in Likert scale). Borg CR-10 (category-ratio anchored at 10) used by few authors listed in Table 1 is a combination of category scale and ratio scale[5, 9-10]. The 5-points one dimension Likert scale was used in this study as a compromise between the need to gather adequate information and the length of questionnaire (the number of pages).

The authors have two objectives for this survey; firstly was to have an understanding of Malaysian drivers' general perspective on noise and vibration discomfort in driving and secondly was to investigate whether age and gender should be considered discomfort factors or not. Some previous literatures have shown that age and gender play big roles in discomfort study [10-15]. Based on the literatures, the authors have two main hypotheses. Hypothesis 1 is that men drivers report less discomforts than women drivers. The second hypothesis is noise and vibration has more effects when the car is idle as compared to when the car is accelerating.

2. QUESTIONNAIRE AND SURVEY

2.1 Instrumentation

According to Giles[16], there is so little agreement as to the definition of a survey, and it is entirely dependent on the research context. Face validity is certainly high as this questionnaire is an adaptation of surveys done by few researchers[2, 9, 14]. For pilot 1, there were 3 sections with 13 questions. The first section collected personal information such as gender, smoking habit, height, weight, highest completed education and monthly salary of respondent. Section two asked about driving background and experience and amongst the questions asked were

how many years they have been driving, information on the vehicle that they mostly drive and road type that they mostly used. The final section is the core of the questionnaire which focused on noise and vibration of their car.

In order to learn about Malaysian driver's perception on noise and vibration discomfort while driving, the items asked were divided into idle and accelerating sections. Idle means the engine is running but the vehicle is stationary and accelerating is when the engine is running and the vehicle is moving. Past literatures reported drivers perceive vibration through floor panels, pedals, gearshift lever, seat and steering wheel[9]. The items and layout used in the questionnaire for this particular question is shown in Figure 1.

Degree of discomfort

① No discomfort
② Slight discomfort
③ Discomfort

Definition:
Idle – engine is running but passenger's vehicle is not moving
Accelerating – engine is running and passenger's vehicle is moving

Discomfort factors	Idle					Accelerating				
Floor vibration (F1&F2)	①	②	③	④	⑤	①	②	③	④	⑤
Steering vibration (F3&F4)	①	②	③	④	⑤	①	②	③	④	⑤
Pedal vibration (F5&F6)	①	②	③	④	⑤	①	②	③	④	⑤
Seat vibration (F7&F8)	①	②	③	④	⑤	①	②	③	④	⑤
Interior noise (F9&F10)	①	②	③	④	⑤	①	②	③	④	⑤
Wind/outside noise (F11&F12)	①	②	③	④	⑤	①	②	③	④	⑤
Engine noise (F13&F14)	①	②	③	④	⑤	①	②	③	④	⑤
Tire noise (accelerating)(F15)	①	②	③	④	⑤	①	②	③	④	⑤
Exhaust noise (F16&F17)	①	②	③	④	⑤	①	②	③	④	⑤

Figure 1. Items in noise and vibration section from the questionnaire

Another matrix form question asking about the level of importance of certain characteristics that they thought a vehicle should have. There are 6 items in this question. The questionnaire's closing question is in open-ended form asking for suggestion or comments regarding the questionnaires itself. The questionnaire took about 12-14 minutes to complete. The scale used was 1-no discomfort at all (comfortable), 2-a little discomfort (satisfactory), 3-discomfort, 4-a lot of discomfort and 5- considerable pain.

For pilot 2 and the actual survey, the number of sections remained but the sections were organized differently. Personal information was asked at the end as suggested in the literature[17]. Redeveloping of the questionnaire involves re-wording the items, re-considering the type of rating scales and the verbal tags to be used, and finding means to keep the interest of respondents (i.e. as a function of survey length)[3].

The actual questionnaire took approximately 10 minutes to complete. The scale used was slightly changed to 1-no discomfort, 2-slight discomfort, 3-discomfort, 4-a lot of discomfort and 5-severe discomfort. According to Shen[5], for a discomfort and seat pressure study, a one dimension type of scale is preferred. A bipolar type of scale has negative, positive and zero options. Since considerable pain is too extreme, the semantic was changed to severe discomfort. From pilot 1, none have actually ticked 4 or 5. Hence, it is assumed that current cars have improved a lot.

2.2 Sampling strategy and methodology

The first pilot questionnaire was carried out with only 10 feedbacks received on time. The questionnaire was emailed in word document form and few were approached with the paper-based. The second pilot questionnaire was in the form of online survey. However, the invitation was done through emails and 12 numbers of respondents gave feedback. The actual survey was carried out using paper-based, administered by the investigator, together with the online-based (www.freeonlinesurveys.com) as well as through email. Respondents were untraceable if they responded through the online survey. The number of respondents for the

actual survey was 70 (paper-based and internet-based altogether), however only 63 were valid for analysis. Invitation for the survey was done at car-wash centers and highway rest area for the paper-based, and at automotive and ergonomic related forums in the internet for the online-based.

1. RESULTS

From pilot survey, low correlation between the key items ($p<0.2$) resulted in the deletion of 3 items. The Cronbach's alpha increased from above 0.8 for pilot survey to above 0.9 for the actual survey. For the actual survey, 70 feedbacks were received. However 7 of the data have to be excluded from analysis. It was due to vehicle manufactured before 1990 and answers believed to be fake responses e.g. the respondents answered severe discomfort for almost all items but vehicle model is the latest edition. Table 2 summarizes the general details of the 63 respondents. The respondents can be divided into subgroups consist of 'non-professional' drivers and 'professional' drivers. Porter et al.[15] stated that a professional driver would be a person who has to be in the vehicle at least four hours most of the time because the nature of his/her works. A definition of 'professional' driver was annotated in the questionnaire. Among the respondents, 32% claimed they are professionals, 43% claimed as non-professionals and 25% decided not to fill in the information. Out of the 32% professional drivers, 15 respondents were men and only 5 were women.

Table 2 Summary data for the 70 respondents to the survey

	n	*Age (yrs) (mean ±SD)*	*Driving experience (years)*					
			<2	*<5*	*5-10*	*11-15*	*>15*	*Null/other*
Total respondents	63	n=62 33.93±8.05	3	4	23	12	18	3
Subgroups								
Non-professionals	29	n=26 33.80±8.94	3	2	12	1	7	2
professionals	23	n=20 33.70±8.25	-	2	4	8	6	1
unstated	18	n=16 34.50±6.62	-	-	7	3	5	-
Men non-pro	12	n=10 33.90±12.32	2	1	2	1	4	-
Women non-pro	17	n=16 33.75±6.49	1	1	10	-	3	2
Men pro	18	n=15 35.07±8.98	-	2	2	6	5	1
Women pro	5	n=5 29.6±3.58	-	-	2	2	1	-
Women unstated	8	n=7 32.43±4.65	-	-	3	1	2	-
Men unstated	10	n=9 36.11±7.70	-	-	4	2	3	-
		Height (mean±SD)	*Weight (mean±SD)*					
Men		166.71±29.13	*70.59*±13.30					
Women		155.42±6.380	59.54±9.80					

Null/unstated= missing data/no answer was given

From the survey, it is concluded that better and/or more expensive cars that are associated with comfort were owned by respondents of 30 years of age and above. However, this is not always true because only 29% from respondents aged 30 and above actually owned more expensive vehicles. It is also learned that the same respondents earned RM5001-RM10, 000 a month. Again, a respondent earning that salary does not necessarily owned better and/or more expensive cars. 73% of respondents used Malaysian manufactured and/or assembled vehicles (Proton, Perodua, Naza and Inokom). The rest used foreign vehicles such as Toyota, Honda, Mazda, Nissan, Ford and Renault. Only respondents with car manufactured from 1990 and above were considered in the analysis that will be discussed later.

Figure 3 shows the result for question 5 which asked about the degree of discomfort that respondents feel are caused by the 17 factors given (refer Figure 1). With reference to the legend, 0 means missing data or no answer given, 1 no discomfort, 2 slight discomfort, 3 discomfort, 4 a lot of discomfort and 5 severe discomfort. The majority of respondents reported no discomfort with almost all discomfort factors listed. Slight discomfort response is

discussed further as it has the highest percentage of response in terms of discomfort (refer Table 3). Three columns showed higher value in slight discomfort than no discomfort. The respondents felt slightly uncomfortable with outside noise during accelerating (F12) (34%) and engine noise in both idle (F13) and accelerating (F14) (37% and 32% respectively). This is shown in Table 4 according to gender of the respondents.

Table 3 Response percentage for question 5

Level of discomfort	Response percentage (%)
No discomfort	46
Slight discomfort	27
Discomfort	13
A lot of discomfort	10
Severe discomfort	4
Missing value	2
Total	100

Table 4 Men and women drivers' perception on three highest slight discomfort responses factors

		out noise acc (F12)		eng noise idle (F13)		eng noise acc (F14)	
		slight discomfort	discomfort	slight discomfort	discomfort	slight discomfort	discomfort
gender	men	18%	8%	24%	6%	16%	10%
	women	16%	8%	11%	13%	14%	8%
Total		34%	16%	35%	19%	30%	18%

Figure 4 depicts that women had reported more discomfort than men in at least eleven out of seventeen factors. It can be seen that women complaints (slight discomfort legend number 2) were more dominant in floor vibration (idle (F1) and accelerating (F2)), pedal vibration (idle (F5) and accelerating (F6) and seat vibration (idle (F7) and accelerating (F8)). It can be presumed that the reason is women respondents are generally anthropometrically smaller in size (refer Table 2).The correlation between these factors are significantly high (0.58 to 0.86 at 0.01 significant level) as compared to the other factors (less than 0.5 at 0.01 significant level). Men have more complaints on factors related to noise (F9-F14 and F17). It is also found their responses are more consistent for all the factors at almost every levels of discomfort. The fact that men are more interested in their vehicle than women would be a substantial reason for the consistent trends.

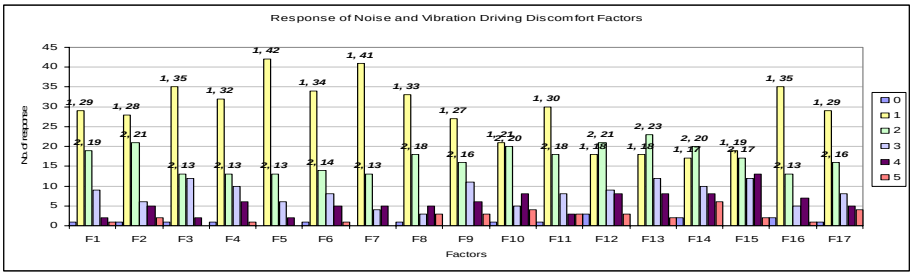

Figure 3 Response for degree of discomfort caused by 17 given factors

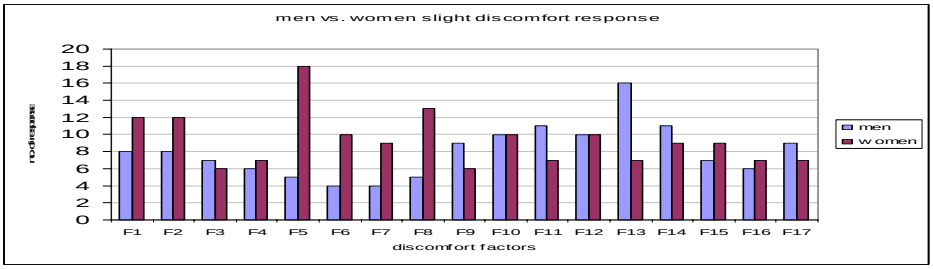

Figure 4 Comparison of men and women drivers for slight discomfort response.

Figure 5 below is the result of driver's perception on vehicle characteristic that they think a vehicle should have. The majority (56%) thought a driver seat comfort as a compulsory characteristic of a vehicle. 40% voted exterior styling as compulsory, 38% voted driving comfort (minimum vibration), 37% voted interior styling, 24% voted drive quietness and 11% voted engine power as compulsory. Table 5 showed results for very important and compulsory according to gender.

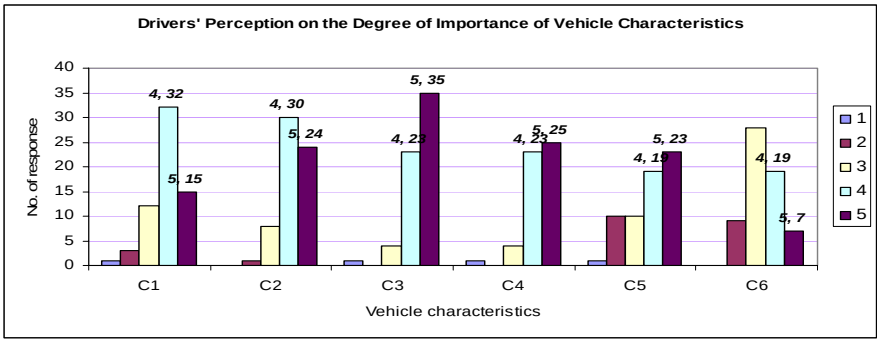

Figure 5 Level of importance of vehicle characteristics as perceived by respondents.

Table 5 Perception of men and women drivers on the importance of six vehicle characteristics

Car characteristics		Drive quietness		Driving comfort		Driver seat comfort		Exterior styling		Interior styling		Engine power	
Degree of importance		4	5	4	5	4	5	4	5	4	5	4	5
gender	male	24	18	19	24	14	32	16	21	11	10	19	14
	female	27	6	27	14	19	25	13	18	18	2	30	3

all value in percentage 4= very important 5= compulsory

With respect to driving experiences, 70% of respondents have more than 5 years driving experiences and only 30% have less than 5 years driving experiences. 35% of the total responses for slight discomfort for F13 (engine noise during idle) comes from respondents with more than 5 years driving experience and only 33% from respondents with less than 5 years driving experience . Out of the total responses from respondents aged 30 years old and below, only 26% thought that F13 was slightly discomfort while majority of them thought it was no discomfort at all. In the case of respondents above 30 years old, 44% thought F13 was slightly discomfort. However the difference of responses between the two groups of ages was not statistically significant (p=0.05).

4. DISCUSSION

4.1 Hypothesis 1

It is concluded based on Table 4 and Figure 4 & 6 that the initial hypothesis, hypothesis 1 should be modified. This is because the findings did not fully support the hypothesis. It is mostly true only for factors related to vibration especially steering and pedal vibration, at least for slight discomfort and discomfort responses. A similar conclusion was made by Giacomin and Gnanasekaran[9] in their study on steering wheel intensity vibration in which they have suggested that women drivers reported more discomfort than men in at least 7 of 28 conditions they investigated. For the other two levels of discomforts i.e. a lot of discomfort and severe discomfort (refer Figure 7 and Figure 8), the number of responses are not significant enough to support the hypothesis. It is with the assumption that women drivers are

physically smaller and as such they are more affected to vibrations during driving. On the other hand, men drivers are well-suited to the seat and their body masses are more tolerable to the vibration. Further more they are more enthusiastic and passionate towards cars and the like. Hence they are more precise in terms of noise. The fact that their body fits the seat better, they felt more comfortable than women drivers.

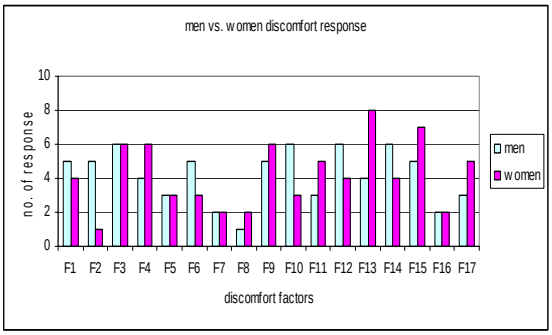

Figure 6 Response for discomfort

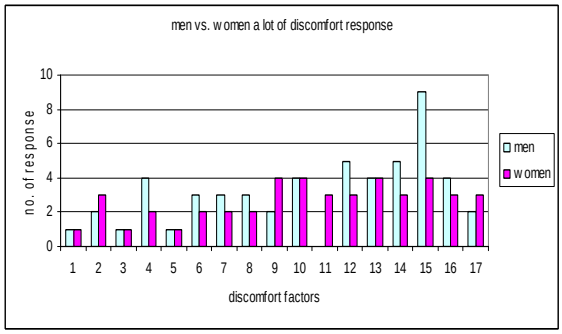

Figure 7 Response for a lot of discomfort

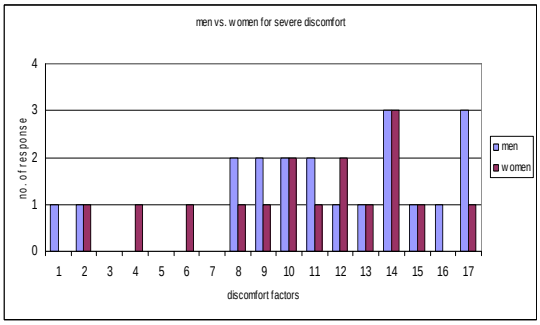

Figure 8 Response for severe discomfort

4.2 Hypothesis 2

Based on the result shown in Figure 3, hypothesis 2 has to be rejected although it was found that in pilot test 1 that noise and vibration have more effects during idle than in accelerating condition. However, with the limited number of respondents, no significant differences can be shown between responses for accelerating condition and idle condition (p=0.05). A possible explanation is that the pilot study was carried out using emails and paper-based questionnaire. Hence, respondents have the means to interact with the authors for clarification and explanation for any uncertainties, in which some of the respondents did. The online-based in the actual survey were truly self-reported type of survey. Although the authors had welcomed any questions or suggestions from her explanatory note, none did so. Given the results of this study, further research appears necessary in order to clarify this point.

5. CONCLUSION

From the study, it was found that the majority of the respondents thought engine noise during idle were the most discomfort item among the 17 items investigated. This was based on the response for slight discomfort which was the most significant level of discomfort in the study. The study also revealed that the initial hypothesis was not true for all the items investigated. Only items related to vibrations showed more discomfort responses from women drivers. It

was also revealed that hypothesis 2 was only true for engine noise during idle slight discomfort response only.

The objective of the study described earlier was to investigate the Malaysian drivers' general perspective on noise and vibration discomfort in driving however the result are not representative of the general perceptions in Malaysia. This is because the numbers of respondents were only 63 due to time and resources limitation. The differences of age and gender role in their perspective of driving discomforts can only be shown in percentage however are not statistically significant. Therefore, further research is needed.

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REFERENCES

1 Smith, D.R., Andrews, D.M.&Wawrow, P.T. Development and evaluation of the automotive seating discomfort questionnaire (ASDQ). *International Journal of Industrial Ergonomics*, **36**, 141-149, (2006)

2 Mansfield, N.J. and Marshall, J.M. Symptoms of musculoskeletal disorders in stage rally drivers and co-drivers, *Br. J. Sports Med.* **35**, 314-320, (2001)

3 White, P.L. & Kolich, M. Reliability and vailidity of a long term survey for auto seat comfort, *International Journal of Vehicle Design* Vol. 34 No. 2 pp158-167, (2004)

4 Klaebo, R., Ohrstrom, E., Rise, I.H.T., Bendsten, H. and Nykanen, H. Vibration in dwellings from road and rail traffic - Part III: towards a common methodology for socio-vibrational surveys, *Applied Acoustics* **64**, 1, 110-120, (2003)

5 Wenqi, S. and Parsons, K.C. Validity and reliability of rating scales for seated pressure discomfort, *International Journal of Industrial Ergonomics*,**20**, 441-461, (1997)

6 Schneider, L.W. and Ricci, L.L. Survey of driver seating discomfort and related factors. *UMTRI-89-23 Technical repor,*. (1989)

7 Reed, M.P. and Schneider, L.W. Design criteria for automobile seatbacks based on preferred driver postures. *UMTRI-95-13 Technical report*, (1995).

8 Winter, D. (1993). Getting the vibes: NVH challenging engineers, *Ward's Auto World* (online - 20/9/2006)

9 Giacomin, J. and Gnanasekaran, S. Driver estimation of steering wheel vibration intensity: questionnaire-based durvey *Engineering Integrity* **18,** 23-29, (2005)

10 Giacomin, J. and Screti, A. Self-reported upper body discomfort due to driving: effect of driving experience, gender and automobile age, *Zeitschrift fur Arbeitswissenschaft*, **5** (2005)

11 Pinkelman, B. Understanding and modeling Seat J.D. Power and Associates APEAL survey results, *SAE paper 2006-01-1303*, (2006)

12 Wyerman, B., Baker, B., Dunsmore, M., Carey, A., Saha, P. and Hadi, R. Automotive noise and vibration control practices in the new millenium, *SAE paper 2003-01-1589*, (2003)

13 Repik, E.P. Historical perspective on vehicle interior noise development *SAE paper 2003-01-1518*, (2003)

14 Kolich, M. and Taboun, S.M. Ergonomics modeling and evaluation of automobile seat comfort, *Ergonomics*, **47** (8), 841-863, (2004)

15 Porter, J.M., Porter, C.S., Lee, V.J.A. A survey of driver discomfort. In: Lovesley, E.J., ed. *Contemporary ergonomics*. London: Taylor and Francis, (1992).

16 Giles, D.C. *Advances research methods in psychology*, Routledge, Great Britain, (2002).

17 Mitchell, M.&Jolley, J. (2001). *Research design explained*, Thomson Learning, US.