Study of subjective responses on ride comfort in public transport Uttarakhand State buses

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Abstract

Today, ride comfort has developed facets that are as significant as safety and speed in assessing the physical characteristics of transportation. The road roughness and vehicle vibration play a predominant role in the subjective evaluation of the ride comfort and activity comfort. The quality of life on board road vehicles is influenced by the level of ride comfort which is basically related to vibration levels and the perception of fatigue. The present study encompasses a questionnaire based study conducted on public transport buses in India, in different routes between Roorkee to Hardwar, Hardwar to Roorkee, and Saharanpur to Roorkee together with vibration measurements on the seat and floor with vertical (z) and lateral (y) directions. The subjective study involved reading of a national Hindi newspaper, to obtain a subjective opinion and to quantify the difficulty in reading and also from the vibration measurements the seat accelerations were measured for suggesting the proper design of seats in public transportation buses. The Preference technique method was adopted and the level of discomfort analyzed in 7- point Semantic scale. The conclusions from the seat location, postures adapted for reading and the vibration measurements served as useful guidelines for conducting experimental work in the Laboratory.

Keywords- Ride comfort, vibration measurements, seven point semantic scale

I. INTRODUCTION

Public transport buses in India transport a large number of passengers every day, not only in the cities but also in rural areas. Hence, buses are a popular mode of travelling in India. Although there are standards available for evaluation of ride comfort in vehicles but none of them consider the effects that vibrations have on particular passengers' activities, [1]. There are many factors in this environment that will disturb passenger's activities. Some of the main sources of disturbance are noise and vibrations generated from the bus itself. A pilot study conducted on passenger comfort reports useful responses to the questionnaire survey and helps to evaluate the ride comfort on their activities [2]. The field study to gauge vibro-acoustical comfort inside the vehicle compartment and quantified a vehicle acoustical comfort index using objective and subjective assessments with the aim of estimating vibration comfort from the analysis of the road condition parameters, such as the International Roughness Index (IRI), and their correlation with kurtosis and the Vibration Dose Value (VDV) to predict the road roughness on the passenger vibration comfort [3]. The experiments on reading ability with size and case of type using stimuli had found reading goes forward in many ways at once rather than through an orderly sequence of operations, consistent with the reader's skills and the requirements of the task. Principal theories of performance appear impulsive in the absence of detailed analysis of task components [4]. Experimental evaluation of ride comfort using multiple regression analysis was performed and good predictability on human dynamic and the ride values of passenger cars were investigated for Korean subjects based on the vibration of the human bodies [5]. The acceleration was measured at 12 points on their bodies according to Griffin's 12 axes in three subjects riding vehicle. The effective amplitude , transmissibility, ride value, ride indices for four different vehicles using frequency weighing was studied considering the seat dynamic characteristics with subjects [6]. The field study on three types of Inter-regional trains during normal service with both questionnaire survey and vibration measurements and reported that 80% of the passengers were reading at some point during the journey, 25% were written by hand, and 14% worked with portable computers. Several laboratory studies were performed for investigating the influence of whole body vibrations in the three translational directions independently and simultaneously similar to experience during train travel, on reading and sketching ability for low-frequency random vibration within the frequency range (1–10 Hz) at 0.5, 1.0 and 1.5 m/s^2 and measured the level of discomfort on perceived difficulty in reading and sketching using 7-point discomfort judging scale [7]. In the present study, a questionnaire based study was conducted on three different bus routes between Roorkee to Hardwar, Hardwar to Roorkee and Saharanpur to Roorkee in public transport buses in India to obtain subjective opinion on discomfort during travel. The objective of the present work is to enhance the understanding on bus travel comfort which could be utilized by bus operators and bus manufacturers in their work.

II. METHODOLOGY

The field study was conducted on public transportation buses in three different routes between Roorkee – Hardwar, Hardwar – Roorkee, Saharanpur – Roorkee.

III. VIBRATION MEASUREMENTS

The vibration measurements were made in all three above mentioned routes and the vibration samples were acquired with integration period of 1second and each individual measurement with 40 seconds duration using 4 Channel sound and vibration meter (SVAN 958) and the mean noise level was acquired using (CESVA SC 310 Integrating-averaging sound level meter and spectrum analyzer). Unweighted accelerations on the floor and on the passenger seat were measured with PCB tri-axial ICP seat pad accelerometers, model 356B41. The vibration amplitudes recorded from floor and seat during travel are investigated for possible artifacts and any unclear signals detected are removed. The mean vibration levels (rms-unweighted) measured along vertical axis and lateral axis at floor and seat. The vector sum is calculated root sum of square (rss) were calculated and shown in Table 1. The noise level obtained inside buses for all three routes is mentioned in Table 2. The FFT of vibration measurements root mean square (rms accelerations) in vertical (z) direction were truncated to show the frequency range of interest up to 30 Hz for clarity as shown in Fig. 5 and 6. Similarly vibration measurements were made in lateral (y) directions. From Fig.5, it is seen that acceleration is 0.82 m/s^2 magnitude at the seat with a resonance frequency at 4.76 Hz and Fig. 6 shows acceleration of 2.22 m/s^2 at the floor at 4.94Hz frequency. Good seats should have a resonance frequency that should be at least 1.4 times lower than the principal resonance frequency of the vehicle where the seat is mounted [8]. But in the present study it is noticed that the resonance frequency at seats is amplifying rather than attenuating due to poor design and improper maintenance of seats. Therefore, it could be possible that the main source of discomfort for performing sedentary activities was due to augmentation of the vibration from the seat. To determine a relationship between buses vibration and passenger discomfort in performing sedentary activities, the results of questionnaire survey have been compared with vibration and noise level for all above mentioned route buses. The effects of vibration frequency, viewing distance and multiple frequency motions on the reading of numeric characters in vertical (z) direction was measured and degradation of the reading task found in the frequency range 2.8 Hz to 63 Hz, where the effect at 3.15 Hz vibration was found to increase more faster with reductions in viewing distance than that of higher frequency at16 Hz vibration, Lewis and Griffin [9]. The measured acceleration range of all the buses in the vertical direction is 0.82 – 2.85 m/s^2 at the seat location, while the range is 2.22 – 2.64 m/s^2 at the floor. The mean and standard deviation of seat acceleration in the vertical direction in all buses are 1.95 m/s^2 and 1.45 m/s^2, respectively and on the floor the corresponding values are 2.47 m/s^2 and 0.30 m/s^2. Similarly, the measured acceleration range for all the buses in the lateral direction is 0.10 – 1.22 m/s^2 at the seat location, while the range is 0.16 – 0.94 m/s^2 at the floor. The mean and standard deviation of seat acceleration in the lateral direction in all buses are 0.17 m/s^2 and 0.85 m/s^2, respectively and on the floor the corresponding values are 0.57 m/s^2 and 0.48 m/s^2.

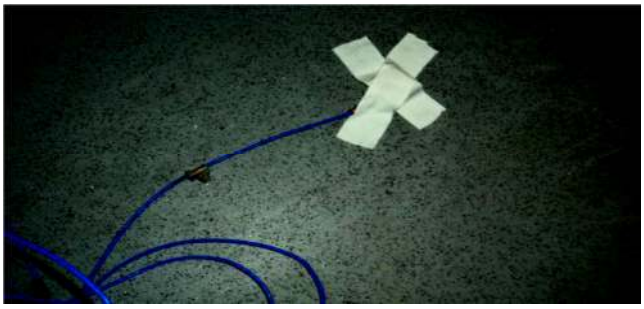

Fig. 1 Measurement of floor acceleration

Fig. 2 Sound and vibration meter, SVAN 958

Fig. 3 Measurement of floor and seat accelerations

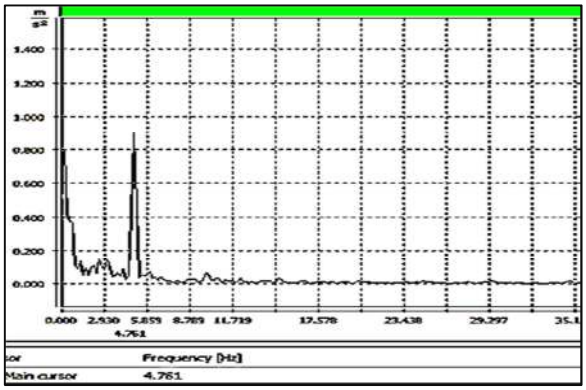

Fig.4 Acceleration at bus seat in vertical direction for Haridwar-Roorkee route.

TABLE. 1 RECORD OF ACCELERATION AMPLITUDE IN VERTICAL (Z) AND LATERAL (Y) TRANSLATIONAL AXES OF MOTION.

BUS ROUTE	**Seat (m/s^2)**			**Floor (m/s^2)**		
	Z	***Y***	***RSS***	***Z***	***Y***	***RSS***
Roorkee to Hardwar	0.82	0.10	0.83	2.22	0.16	2.22
Haridwar to Roorkee	2.85	1.22	3.10	2.64	0.63	2.71
Saharanpur to Roorkee	2.18	1.15	2.46	2.55	0.94	2.71
Mean	1.95	0.82	2.13	2.47	0.57	2.54
M nimum	0.82	0.1	0.83	2.22	0.16	2.22
Maximum	2.85	1.22	3.1	2.64	0.94	2.71

TABLE. 2 MEAN NOISE LEVEL IN THREE ROUTE BUSES.

BUS ROUTE	**Noise level (DB)**
Roorkee to Hardwar	76
Haridwar to Roorkee	70
Saharanpur to Roorkee	72

TABLE. 3 SEVEN POINT SEMANTIC SCALE

1	2	3	4	5	6	7

Excellent Extremely poor

Fig.5 Acceleration at bus seat in lateral direction for Haridwar-Roorkee route.

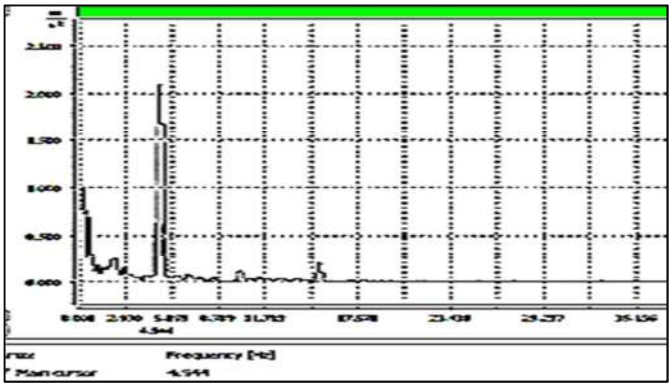

Fig. 6 Number of passengers adopted different postures for reading activity in three routes.

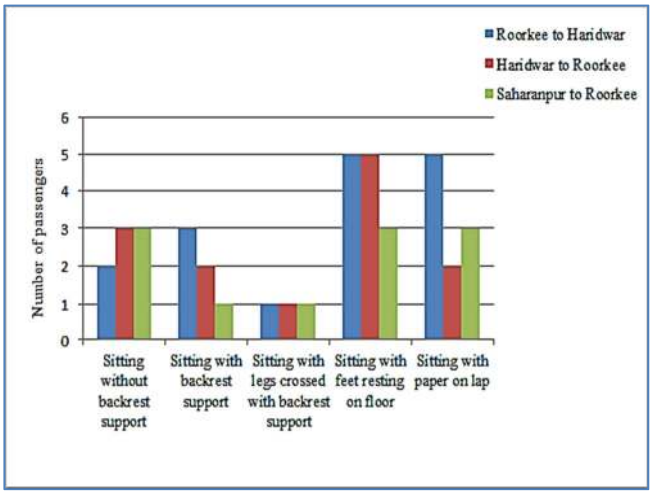

TABLE. 4 SITTING POSTURES ADOPTED WHILE READING THE HINDI NEWSPAPER IN THREE ROUTES

Routes	**Sitting without backrest support**	**Sitting with backrest support**	**Sitting with legs crossed with backrest support**	**Sitting with feet rest on floor**	**Sitting with paper on lap**
Roorkee - Haridwar	2	3	1	5	5
Haridwar - Roorkee	3	2	1	5	2
Saharanpur - Roorkee	3	1	1	3	3

IV. QUESTIONNAIRE SURVEY

The passengers' subjective opinion was obtained to quantify the difficulty in reading a national newspaper. A copy each of a national Hindi newspaper was distributed to the passengers and they were instructed to read for 40 seconds during their journey, while simultaneously accelerations from the vibration was measured on floor and seat. The questionnaire consisted of ride comfort and activity comfort related questions based on a seven point semantic scales from excellent to extremely poor (Table 3). The questionnaire consisted of 26 questions related to general background of the participants, information about present journey, types of sedentary activities and time spent on each activity, position of seating, drinking water and sleeping activity, postural positions related to the reported activities, a reading national Hindi newspaper for quantifying the difficulties of reading while the bus is running and a self-rating of the performance and feeling from disturbances from noise, vibration, jerks, etc. in the buses. The questions were formulated using both preference and magnitude scaling techniques in order to obtain qualitative and quantitative information related to the effects of vibrations on the performance of sedentary activities and postural positions. Questions related to the postural positions were formulated using preference technique. On the other hand, questions related to vibrations and jerks were formulated using magnitude scaling technique. Here the subjects were asked to rate their feelings on a 7-points Semantic scale. The two extreme points were marked as "Excellent" and "Extremely poor". The rate of difficulty in reading the newspaper is quantified with percentage of passengers feeling comfort and discomfort due to several factors like road-humps, vibration, noise, sudden shocks, jerks, and others.

V. RESULTS AND DISCUSSION

Fig. 7 shows number of passengers performing reading activity in different postures on three routes. The postures adopted by the commuters are sitting without backrest support, sitting with backrest support, sitting with legs crossed with backrest support, sitting with feet resting on floor and sitting with paper on lap. Fig. 7 results are tabulated in Table.4 it shows that most of the bus passengers prefer reading paper on postures that eliminate backrest support. This is anticipated, since the greater vibrations are transmitted from the backrest and the upper torso and head motion are affected. From Fig.8 the percentage of sedentary activities performed in three routes has been found. In Roorkee to Hardwar route, passengers performed activities like drinking water 18%, reading 44%, sleeping 14% and others 24%. In Hardwar to Roorkee route, drinking water 42%, reading 30% sleeping 10% and others 18%. In Saharanpur to Roorkee route, drinking water 38%, reading 40%, sleeping 11% and others 11%. From these above results it has been found the passengers perform reading and sleeping activity more in their journey and they perform other activities like chatting and they also relax when they are tired by drinking water. From Fig.8 the different factors causing discomfort in three routes while reading Hindi newspaper on passenger's using questionnaire based on seven point scale. From the study it's been found passengers feel more discomfort from vibration and noise mostly compared to other factors like road humps, oscillation, and sudden shocks. In all three routes 12 passengers reported difficulty in vibration and noise and 4 passengers found extreme difficulty from road humps, 5 passengers faced discomfort from oscillation and 10 passengers from sudden shocks.

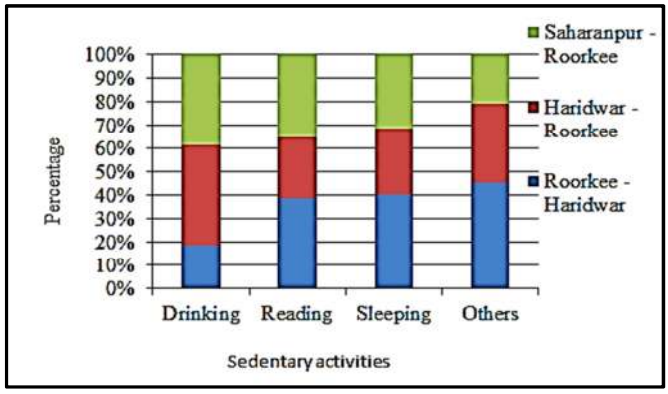

Fig.7 Passengers percentage of sedentary activities in three routes

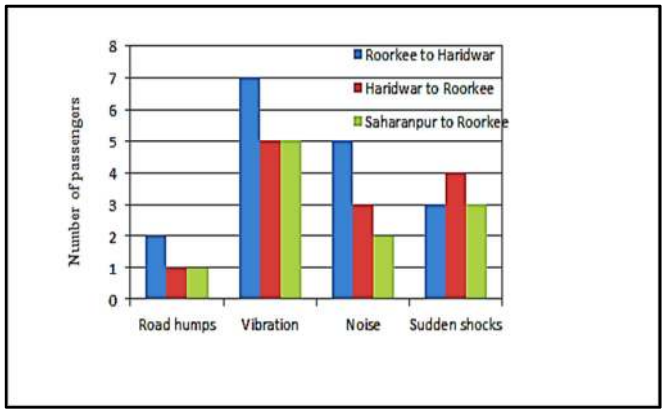

Fig. 8 Factors causing discomfort in three routes while reading a Hindi newspaper.

VI. CONCLUSION

The present study quantified percentage of discomfort due to vibration and noise on sedentary activities. The vibration measurements have been made on the floor and seat of the buses and unweighted rms acceleration is acquired for analysis of discomfort. The measured accelerations were correlated with the response from questionnaire survey for passenger's subjective opinion. The questionnaire analysis in three route buses found reading activity is disturbed considerably due to vibration. The postural effects on reading activity has been found on sitting with backrest and foot rested on floor causing more discomfort due to the excitation of supporting structures on human body. The amplification of the vibration was found on the passenger seat as compared to the measurement of vibration on the floor. It has been found that the maximum acceleration of 2.85 m/s^2 in Haridwar to Roorkee route in seated passengers whereas 2.64 m/s^2 in floor vibration measurement. The main aim of this field study is to increase knowledge on passenger needs to be able to suggest improvements on bus comfort. The suggested improvements will support bus operators and bus manufacturers in their work.

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