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Experiment and optimisation analysis of whole-body vibration among tractor drivers: a comprehensive study

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Abstract: This study investigates the impact of whole-body vibration (WBV) in terms of daily vibration exposure (A(8)) at seat-pan, weighted acceleration response (A_{wz}) at seat-base, and Health Guidance Caution Zones (HGCZ), and vibration damping ratio (VDR) among three tractor drivers. Three ride conditions were considered i.e., average forward speeds (5-Levels), road roughness (5-Levels), and two driving postures (sitting vertically erect with a backrest position (P1) and sitting freestyle with no backrest contact (P2)) utilised to arrange the experiments by response surface methodology (RSM) design. The total vibration (a_v) was observed from 0.62–1 m/s^2, 0.6–0.94 m/s^2, and 0.49–0.9 m/s^2 for tractor drivers (TD) 1, 2, and 3, respectively. Optimised ride conditions were average speed (6.37 m/s), road IRI (2.28 m/km), and P2 among all the selected drivers. Moreover, the best suitable linear regression model is found with 97.73% and 97.57% desirability for drivers first and second, respectively.

Keywords: whole body vibration; daily dose A(8); HGCZ; health guidance caution zones; optimisation design; tractor; road international roughness index; body mass index.

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1 Introduction

Agriculture tractors are extensively used for both on-road and off-road transportation activities. It is widely recognised that tractor drivers are exposed to high levels of vibration during on-road and off-road operations (Scarlett et al., 2007). Drivers of agriculture tractors are exposed to whole-body vibration (WBV) which may lead to human fatigue, causing agriculture-related operation accidents and other problems (Zehsaz et al., 2011). Vibration arises from the tractor due to tractor-tiller interaction with an uneven surface (Mehta et al., 1997). The vibration transmits through different source points of the tractor, such as the floor, seat, and steering (Village et al., 2012). The tractor vibrations not only reduce the comfort, impair activities, and cause other health degradation of the driver but also increase the dynamic stress that may lead to fatigue and failure of the tractor component (Prasad et al., 1995). Prolonged exposure to the occupation's WBV leads to significant health concerns such as musculoskeletal disorders and low back pain among tractor drivers (Hildebrand et al., 2008; Solecki, 2010). Drivers are exposed to WBV above the recommendation limits during field operations (Nupur et al., 2013). Exposure to WBV has been linked to an increase in spinal degeneration among tractor-trailer truck drivers, forklift workers, and drivers in the transportation sector (Sujatha et al., 1995). Several studies reported a higher prevalence of low back pain among professional drivers with frequent exposure as compared to the general population such as tractors (81%), trucks (50%), buses (81%), and forklifts (57%) (Bovenzi, 2009). The daily WBV limit for a driver in 8 h working period in a day is set as per (EU Directive 2002/22/EU, ISO 2631-1:1997).

A high level of vibration occurs during different operations, including tractor seats (Smith and Leggat, 2005). Long-duration exposure may lead to some adverse health effects (back pain, spine degeneration, and other disc diseases) among tractor drivers (Hulshof and van Zanten, 1987; Ranganathan and Mohan, 1997; Smith and Leggat, 2005). Because the tractor does not contain an advanced suspension system and produces a high level of vibrations as compared to other vehicles under similar road conditions.

It has become more important towards the range of the human body's natural frequency. Boshuizen et al. (1990) reported a more frequent occurrence of back pain among tractor drivers in comparison to the drivers of other vehicles (Boshuizen et al., 1990).

In addition, the transmission of vibrations in tractor driving occurs at low frequencies, which may lead to discomfort related to the natural frequencies of human body parts already in existence at the time of transmission (Liang and Chiang, 2008). The problem of tractor rides becomes more critical when tractor vibration resonance frequencies occur between 1–7 Hz, which is responsible for several health effects in the human body. For example, the natural frequencies of the human trunk and lumbar vertebrae are 4–8 Hz and 4–5 Hz, respectively, in the normal state (Griffin, 1990). For this reason, the tractor seat must be designed to prevent vibrations within this range. The amount of riding vibrations seems to need further decrease, and several viable ways for obtaining major improvements have been detailed (Prasad et al., 1995). WBV is highly dependent on the body anatomy of the driver, the vehicle's mass, weight distributions, tyre inflation pressures, and the ground surface (Scarlett et al., 2007). The impedance of the seat, as well as the apparent mass of the seat passenger, determines the amount of vibration that is transferred through the seat (Toward and Griffin, 2011).

The reduction of vibration transmission is dependent on two basic factors (Tiemessen et al., 2007). The first is a design consideration of the manufacturer with minimum WBV exposure from different source points such as steering, floor, and suspended seat (Donati, 2002; Reina and Rose, 2016). The second category is education which is an important factor for drivers. Many studies have been evaluated by focusing on the dynamic behaviour of the driver in commercial vehicles (Macadam, 2003). Driver education is the key factor to reduce WBV transmission (Nawayseh and Griffin, 2009). Similarly, it has been proven that the education of drivers not only helps to reduce fuel consumption but it also has a significant positive influence on the reduction of WBV exposure (Jönsson et al., 2007).

The majority of the previous studies have been carried out on simulators to investigate the impact of various parameters on the ride, such as the amount of vibration (Çiloğlu et al., 2015), sitting position (Mandapuram et al., 2010), seat backrest (Nawayseh and Griffin, 2005), and so on. However, only a few studies have taken into account vibration exposure in real-world driving settings on-road (Nawayseh, 2015). Tewari and Prasad (2000) investigated ride comfort by taking the input parameters such as seat pan curvature, backrest inclination, and curvature, and the results provide an optimum radius of curvature and inclination in this study. Jayasuriya and Sangpradit (2014) developed a suspended seat providing a significant damping system to mitigate the transmission of vibration into the driver (Jayasuriya and Sangpradit, 2014). Several studies have been done to improve ride comfort by analysing the different parameters such as seat suspension (Marsili et al., 2002), axle suspension (Lehtonen and Juhala, 2005), shock absorbers (Deprez et al., 2005), tyre inflation (Cuong et al., 2013), forward speed (Scarlett et al., 2007; Singh et al., 2018; Son et al., 2017) is the major vibration transmission source into the human body. Devangan et al. (2015) investigated the effect of Body Mass Index (BMI) and showed the significant impact of the seated interface pressure on the transmission of vibration in the human body (Dewangan et al., 2015). The large variety of surface combinations, machine settings (such as tyre pressure, presence of ballasts and implements), forward speed, and driver behaviour generate large ranges of produce unexpected accelerations. Consequently, hitherto little research has been conducted to mitigate the transmission of WBV.

From these studies, it is clear that the tractor manufacturers interested in improving the design to mitigate the vibrations need to pay attention to several factors such as axle suspension, seat suspension, forward speeds, and tyre inflation pressure. Yet some other parameters such as road roughness in on-road operation, BMI stature, and body posture with varying different, forward speeds during on-road transportation on a tractor in real-time experimentation still need to be investigated. To find out the optimum transmission of WBV, there is a need to use some advanced optimisation techniques like the response surface methodology (RSM) for designing the experiments to save time and effort. In the current study, the effects of average forward speed, road roughness, Body Mass Index (BMI), and Posture on ride comfort in terms of daily vibration exposure A (8), tractor floor vibrations (A_{wz}), and Vibration Damping Ratio (VDR) have been studied experimentally. Further, Fast Fourier Transform (FFT) analysis has been done to find the resonance frequencies among the selected postures.

2 Methodology

The detailed methodology of the current study was as follows:

2.1 Tractor drivers

Three tractor drivers (TD1; TD2; TD3) with a mean age of 27.67 years, a body weight of 74.33 kg, a stature of 1.55 m, and a body mass index (BMI) of 30.97 kg/m^2 were recruited for this study. The detailed demographic information of each tractor has been stated in Table 1. Primarily, this study focused on recruiting a driver from three different BMI categories, i.e., overweight (26.4 kg/m^2), obese class I (30.3 kg/m^2), and obese class II (36.2 kg/m^2) as per (WHO BMI classification 2020).

Table 1 Demographical information of recruited tractor drivers

Tractor drivers	*TD1*	*TD2*	*TD3*	*Mean ± St. dev*
Age (years)	27	28	28	27.67 ± 0.577
Weight (kg)	64	72	87	74.33 ± 11.676
Height (m)	1.554	1.542	1.551	1.55 ± 0.006
BMI (kg/m^2)	26.4	30.3	36.2	30.97 ± 4.934

This particular selection was in line with the ICMR 2020 or World Health Organisation (WHO), 2004 report which concluded that the majority of the Indian population lies under and/or above the overweight category. The recruited drivers belonging to farming backgrounds have a minimum of five years of experience in operating a tractor. The daily driving duration of the selected drivers was a minimum of 4 h a day and five days a week. Before performing the experiments, the objective of the current study has been described to all the drivers. To obtain the general health status, each of the drivers was asked to report any sensitivity toward vibration exposure. In response, none of the drivers reported any such kind of issue while exposed to ride vibrations. This study has followed the Declaration of Helsinki (WMA, 2013), and the protocol was approved by the Research advisory committee of Dr. BR Ambedkar National Institute of Technology Jalandhar, Punjab (India) [vide letter no. NITJ/IPE/RA/113].

2.2 Experimental design

In this study, three input parameters were considered, namely: tractor speed, road roughness, and driving posture. Tractor speed was varied at five different levels, i.e., 6.37, 6.94, 8.33, 9.72, and 10.34 m/s. These speed levels were selected based on random pilot experiments. The data retrieved from the pilot experimentation has not been included in this study. Further, the five different terrain conditions were considered, i.e., Airport Road, National highway, State highway, Village road, and cemented State highway road located in Punjab (India), as shown in Figure 1. The representation of the experimental setup is shown in Figure 2.

Figure 1 Representation of five terrains: (a) national highway; (b) state highway; (c) airport road; (d) village road and (e) cemented road (see online version for colours)

Figure 2 Mounting of sensors at measuring locations in real experimentation (see online version for colours)

The terrains were subjected to roughness measurement to consider it a quantified parameter. The average attained road international roughness index (IRI) response of each terrain, i.e., Airport roads, National highways, State highways, Village roads, and State highways cemented roads was 2.28, 2.55, 3.20, 4.12, 3.85 m/km, respectively.

Two driving postures, i.e., sitting vertically erect with a backrest position (P1) and sitting freestyle with no backrest contact (P2), were considered for the investigation. The entire information concerning each input parameter has been tabulated in Table 2.

Table 2 Input parameters and corresponding levels

Input parameters	*Level 1*	*Level 2*	*Level 3*	*Level 4*	*Level 5*
Average tractor speed (m/s)	6.37	6.94	8.33	9.72	10.34
Road roughness (m/km)	2.28	2.55	3.20	3.85	4.12
Driving posture	P1	P2	–		

2.3 Test tractor

This study was conducted on the New Holland 3630 tractor of the 2016 model with 55 horsepower (hp) capacity. The detailed specification of a tractor is shown in Table 3. The tractor seat was the same as provided by the original manufacturer during the purchase. The front and rear tyres were changed by fresh ones four months ago, so there was negligible wear and tear issue. In addition, the tyre pressure was kept as prescribed in the tractor catalogue (i.e., 140 kPa) throughout the experimentation.

Table 3 Specification of selected tractor

Engine capacity (cc)	2991
Horsepower (hp)	55
Forward and reverse speed (km/hr)	Max. 38.30 and Max. 14.98
The total weight (kg)	2080
Front-wheel and rear-wheel size (Inch)	14.9×28 and 16.9×28
Hydraulic lifting capacity (kg)	1700/2000
Implements attached via	PTO
Wheelbase, ground clearance, and turning radius (mm)	2045, 445 and 3190
Number of gears	8 forward and 2 reverse
3-point Linkage	Category I & II, Automatic depth & draft control
Fuel capacity (litres)	60

2.4 Instrumentation and data analysis

This section has been divided into further three subsections as defined below:

2.4.1 Evaluation of daily vibration exposure A(8)

To assess the ride comfort, the overall daily vibration exposure has been calculated after measuring the exposure levels on the seat and floor. The suitable multiplication factors and weighting filters related to assessing the ride comfort were taken during the evaluation as per ISO 2631-1 (1997). To determine the A (8), the weighted root means square acceleration magnitude (a_w) has been used along the translation axes. the x-axis (fore-and-aft), y-axis (lateral), and z-axis (vertical). It can be stated mathematically, as mentioned in equations (1) and (2).

$$A_w = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)\,\mathrm{d}t} \tag{1}$$

$$A(8) = kA_w\sqrt{\frac{T_t}{T_0}} \tag{2}$$

where

$a_w(t)$ is instantaneous frequency-weighted acceleration to time.

K is multiplication factors with standard values for the different axes (ISO 2631-1-1997).

T_t is total time, a daily working duration that is 8 h a day as per ILO.

T_o is observed time or measured time.

To determine the severity of A(8) exposure, the output response has been compared with suggested exposure limits (i.e., exposure action value (EAV): 0.5 m/s^2 and exposure limit value (ELV): 1.15 m/s^2) as specified in Directive2002/44/EU. A(8) value greater than the EAV means that there was a risk from vibration exposure that needs to be controlled. There was a high risk if the A(8) value is more than the ELV.

2.4.2 Evaluation of vibration damping ratio (VDR)

In addition, the following equation (3) was used to evaluate the VDR:

$$VDR = 100 \times \frac{a_w seat}{a_w floor} \tag{3}$$

whereas

$a_{w\ \mathrm{seat}}$ was the weighted root mean square acceleration on the seat.

$A_{w\ \mathrm{floor}}$ was the weighted root mean square acceleration on the floor.

The vibration damping ratio (VDR) value indicates the seat vibration isolation capacity, while VDR was less than 100% (<100%) indicating a safe ride (ISO 10326-1, 1992). While the VDR value of more than 100 indicates a terrible ride. It indicates that the vibration isolation capacity was compromised (Paddan and Griffin, 2002).

2.4.3 Evaluation of health guidance caution zones (HGCZ)

The vibration magnitude was measured along with the translational directions namely, vertical (z-axis), transverse (y-axis), and longitudinal (x-axis). After that, the vector sum of all the measured axes' vibration was calculated by taking the different frequency weighting multiple factors such as taking k's value, 1.4 for the *x* and *y* axes, and 1 for the z-axis. The total weighted acceleration (a_v) was calculated by equation (4). This was further used to assess the health guidance caution zone (HGCZ) by following the ISO 2631-1 (1997). The upper and lower boundary limits of the caution zone were taken as 6 m/s^2 and 3 m/s^2, respectively, for calculating the time exposure (Kumar et al., 2001). Vibration acceleration exceeding the upper limit may cause some health effects, whereas below that line there was no risk to health. It can be stated mathematically as mentioned in equations (5) and (6). Equation (5) was used for calculating the upper limit, and equation (6) for the lower limit of HGCZ.

$$a_v = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2} \tag{4}$$

where a_v is the total weighted RMS acceleration.

$$T_u = \frac{1}{6}\left[\frac{T_6}{a_v}\right]^2 \tag{5}$$

$$T_l = \frac{1}{6}\left[\frac{T_3}{a_v}\right]^2 \tag{6}$$

where T_u is the upper limit of time exposure and T_l is the lower limit of time exposure of the caution zone. T_6 and T_3 were 6 m/s^2 and 3 m/s^2, respectively RMS acceleration between 1–10 min of health caution zone (Griffin, 1990). The comfort reaction to the vibration exposures as per 2631-1 (1997) was mentioned in Table 4.

Table 4 Comfort reactions to vibration values as per ISO 2631-1 (1997)

Vibration values	*Comfort reactions*
<0.315 m/s^2	Not uncomfortable
0.315–0.63 m/s^2	A little uncomfortable
0.5–1 m/s^2	Fairly uncomfortable
0.8–1.6 m/s^2	Uncomfortable
1.25–2.5 m/s^2	Very uncomfortable
>2 m/s^2	Extremely uncomfortable

2.5 Design of experiment (DoE)

In this study, the RSM central composite technique has been used to design the experiments. RSM was defined as a statistical and mathematical technique that can be used to analyse the interaction between factors and responses. The primary goal of this strategy was to optimise the potential factors to predict the most accurate responses (Montgomery, 2008). A three-level full factorial central composite design was employed, requiring 28 experiments (calculated based on equation (7)) which consisted of 8 factorial runs, 8 axial runs, and 6 centre runs.

$$N = 2^n + 2n + n_c \tag{7}$$

where N is the total number of experiments and n is the number of factors and n_c is centre runs.

The alpha value of the design was 1.41421. The response for this experiment is (Y), which was developed by an empirical model that uses a second-degree polynomial to link the response to the three-level components, as shown in equation (8).

$$Y = b_0 + \sum_{i=1}^{n} b_i X_i + \sum_{i=1}^{n} b_{ii} X_{ii} + \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} b_{ij} X_i X_j \tag{8}$$

where Y is the predicted response, b_o is a constant coefficient, b_i is a linear coefficient, b_{ii} is the quadratic coefficient, b_{ij} is an interaction coefficient, X_i and X_j are the coded values.

2.6 Data analysis

The raw data from two sources along with three translation axes was recorded and transferred to SVANPC++ software to get the room mean square weighted acceleration magnitude. Further, the raw data was saved in a text file format (.txt) and analysed in MATLAB software to find out the FFT responses for each axis. Minitab 17 statistical software was utilised for the design, statistical analysis, mathematical modelling, and optimisation. This study used three factors, two of them were continuous factors (Average Speed and Road Roughness) with five levels and one was a categorical factor (Driving Posture) with two levels as mentioned in Table 2. The average speed was calculated with the traditional method by measuring the distance covered in one minute with the respective gear. Average road roughness was measured by using Z-250 Reference Profiler. In addition, two driving postures (P1 and P2) were selected for this study which was already discussed in Section 2.2. The statistical testing of the linear model was performed by the ANOVA by obtaining the F-test to analyse the interrelationship between output and input parameters. To examine the goodness of fit, each model was tested statistically which conformed to the significance of F-values with $P \leq 0.05$. The values of R^2, adjusted R^2, predicted R^2, lack of fit, and adequate precision of models were obtained to check the quality of the suggested optimised response. The response surface and contour plots were drawn to visualise the input-output relationship.

2.7 Response surface methodology: a design of experiments techniques

Response surface methodology (RSM) is a mathematical and statistical approach for designing a systematic set of experimental trials used to analyse the individual and relative impact of each input parameter on the response parameter(s) (Myers et al., 2016). In the present study, input parameters (listed in Table 2) were randomised to formulate a systematic set design of experiments aiming to analyse their impact on response parameters i.e., vibration daily exposure (A (8)), weighted acceleration along the z-axis (A_{wz}) at the floor and Vibration Damping Ratio (VDR) using RSM approach.

This approach provided 28 experimental trials, and each trial was replicated three times to get the mean response. A tabular view can be visualised in Table 5, to understand the set of an experimental trial. Furthermore, this approach enables the analysis of the significance level for each input parameter in the outcome response, the percentage contribution of each input parameter in impacting the response parameter, and regression models to predict and optimise the response parameters.

Table 5 Arrangement of experiment in 28 sets

	Experimental factors				*Experimental factors*		
Trial no	*Speed-level (1–3)*	*Road IRI-level (1–5)*	*Posture-level (1–2)*	*Trial no.*	*Speed-level (1–3)*	*Road IRI-level (1–5)*	*Posture-level (1–2)*
1	3	5	1	15	4	2	1
2	3	3	2	16	2	4	1
3	3	3	1	17	3	3	1
4	1	3	1	18	3	3	2
5	3	3	1	19	2	2	2
6	3	1	2	20	3	3	1
7	5	3	2	21	3	3	2
8	5	3	1	22	2	2	1
9	3	3	1	23	4	4	2
10	3	3	2	24	3	3	2
11	3	1	1	25	2	4	2
12	1	3	2	26	3	3	1
13	3	5	2	27	4	4	1
14	3	3	2	28	4	2	2

3 Results and discussion

In this study, the full factorial-central composite design was employed, which consists of 28 experiments that include six centre points, six axial points, and eight cube points. The total experiments run with three responses A (8)-seat, A_{wz}-Floor, and VDR percentage are mentioned in Appendix 1. The current study contains the three input parameters (two continuous parameters with five levels and one categorical parameter with two levels) and three output parameters for each BMI category, as mentioned in Appendix 1.

3.1 Health guidance caution zones (HGCZ) on the driver seat

The vibration on the seat has been measured along with the x, y, and z axes mentioned in Appendix 2, so the total vibration (a_v) can be computed. Additionally, the lower and higher HGCZs were analysed to determine the length of exposure and its health impacts on the human body by ISO 2631-1 (1997). The total vibration (a_v), exposure action value (T_l), and ELV (T_u) are mentioned as per the design of experiments in Appendix 3. It has been observed that the magnitude of the vibration on the driver seat was varied from 0.211–0.384 m/s^2, 0.215–0.377 m/s^2, 0.152–0.375 m/s^2 in the longitudinal (x) axis for tractor driver 1, 2 and 3 respectively. Whereas, the transverse (y) axis varied from 0.111–0.192 m/s^2, 0.140–0.313 m/s^2, and 0.103–0.157 m/s^2 for drivers 1, 2, and 3 respectively. However, it was noted that magnitude was dominant in the z-axis on the driving seat. And it varied from 0.434–0.821 m/s^2, 0.432–0.763 m/s^2, and 0.353–0.662 m/s^2 for drivers 1,2, and 3 respectively. The total vibration exposure varies from 0.62–1.00 m/s^2, 0.6–0.94 m/s^2, 0.49–0.9 m/s^2, and exposure action start on 1.5–3.9 h, 1.68–4.21 h, 1.86–6.18 h and the exposure limit start on 5.98–15.59 h, 6.73–16.85 h, 7.43–24.71 h for tractor driver 1, 2 and 3 respectively. Beyond the exposure action and limit, a certain health effect can start (DEO et al., 2021). It was noted that the magnitude of the vibration in the vertical direction increases with increasing speed (DEO et al., 2021). From the ANOVA table, it was noticed that the speed was a significant influencing input parameter affecting the vibration. As per ISO 2631-1 (1997), the tractor driver's total vibration dose lies under the 0.5–1 m/s^2 category, and the comfort reaction was fairly uncomfortable.

3.2 Development of regression equation

The root mean square weighted acceleration response along the translational axes wrt experiment runs are mentioned in Appendix. The response surface linear regression model with codec variable has been evaluated and mentioned in Table 6. It was noted that VDR has been evaluated from the A_{wz} on Seat and A_{wz} on the floor with equation (5). So, further analysis and optimisation were done with daily exposure value on the seat as A(8) and vertical acceleration on the floor as A_{wz}.

Table 6 Driver-wise linear regression equations

TD1	Y_1: A(8)-Seat	–0.2641 + 0.08789 Speed (m/s) + 0.0394 Road IRI (m/km)
	Y_2: A_{wz}-Floor	–0.2579 + 0.08465 Speed (m/s) + 0.0356 Road IRI (m/km)
TD2	Y_3: A(8)-Seat	–0.2174 + 0.07862 Speed (m/s) + 0.0394 Road IRI (m/km)
	Y_4: A_{wz}-Floor	–0.0981 + 0.06345 Speed (m/s) + 0.0383 Road IRI (m/km)
TD3	Y_5: A(8)-Seat	–0.6823 + 0.11682 Speed (m/s) + 0.0832 Road IRI (m/km)
	Y_6: A_{wz}-Floor	–0.1887 + 0.06339 Speed (m/s) + 0.0519 Road IRI (m/km)

In this model, the maximum values in lack of fit were greater than 0.05, which indicates the fitting quality of the model was good as mentioned in ANOVA analysis in response to Y_1, Y_2, Y_3, and Y_5 (Subasi et al., 2016; Xie et al., 2022).

It has been observed that the speed and road IRI were statistically significant for Y_1–Y_6 response parameters. Additionally, input parameter posture was also a considerably significant input parameter in Y_1 and Y_3. At the same time, there was non-significance in Y_2, Y_4, and Y_6 output parameters, which indicates the non-contribution in the floor vibration. The statistical significance fitting accuracy for the response parameters is mentioned in Table 7.

Table 7 Statistical fit analysis of regression equations

Tractor driver		*S*	*R-Sq*	*R-Sq*. (adj.)	*R-Sq*. (Pred.)
TD1	Y_1	0.0265147	93.77%	92.99%	91.73%
	Y_2	0.0373996	87.45%	85.88%	84.18%
TD2	Y_3	0.0271444	92.11%	91.13%	89.01%
	Y_4	0.0373096	80.27%	77.80%	71.98%
TD3	Y_5	0.0694298	80.18%	77.71%	73.36%
	Y_6	0.0413284	77.96%	75.21%	68.35%

The results of significance parameters have been evaluated by the analysis of variance (ANOVA) statistical tool mentioned in Table 8. The validation of the significant parameters was determined by F-test, i.e., the largest f-value and smallest p-value indicate the significance level of the model. It was observed that linear regression coefficients (R^2) and adjusted R^2 (R^2_{adj}) of the model were very close to 1, which indicates how well data was fitted in the linear regression model (Long et al., 2019). Additionally, the difference between adj. and pre. R^2 was 2% in Y1, Y2, and Y3 response factors. This consequence indicates that the model has high accordance with small errors in the sample points (Khed et al., 2020). Moreover, the difference was greater than 2% for Y4, Y5, and Y6. And it can be applied for the subsequent multi-objective optimisation analysis.

Table 8 ANOVA analysis

TD1											
	A (8)- Seat (y_1)					*A_{wz}-Floor (y_2)*					
Source	*DF*	*Adj. SS*	*Adj. MS*	*F-Value*	*P-Value*	*DF*	*Adj. SS*	*Adj. MS*	*F-Value*	*P-Value*	*DF*
Model	3	0.254	0.085	120.450	0.000*	3	0.234	0.078	55.730	0.000*	3
Linear	3	0.254	0.085	120.450	0.000	3	0.234	0.078	55.730	0.000	3
Speed (m/s)	1	0.238	0.238	339.150	0.000*	1	0.221	0.221	158.150	0.000*	1
Road IRI (m/km)	1	0.010	0.010	14.920	0.001*	1	0.009	0.009	6.140	0.021*	1
Posture	1	0.005	0.005	7.300	0.012*	1	0.004	0.004	2.900	0.102	1
Error	24	0.017	0.001			24	0.034	0.001			24
Lack-of-Fit	14	0.013	0.001	2.540	0.072	14	0.014	0.001	0.510	0.878	14
Pure Error	10	0.004	0.000			10	0.020	0.002			10
Total	27	0.271				27	0.267				27

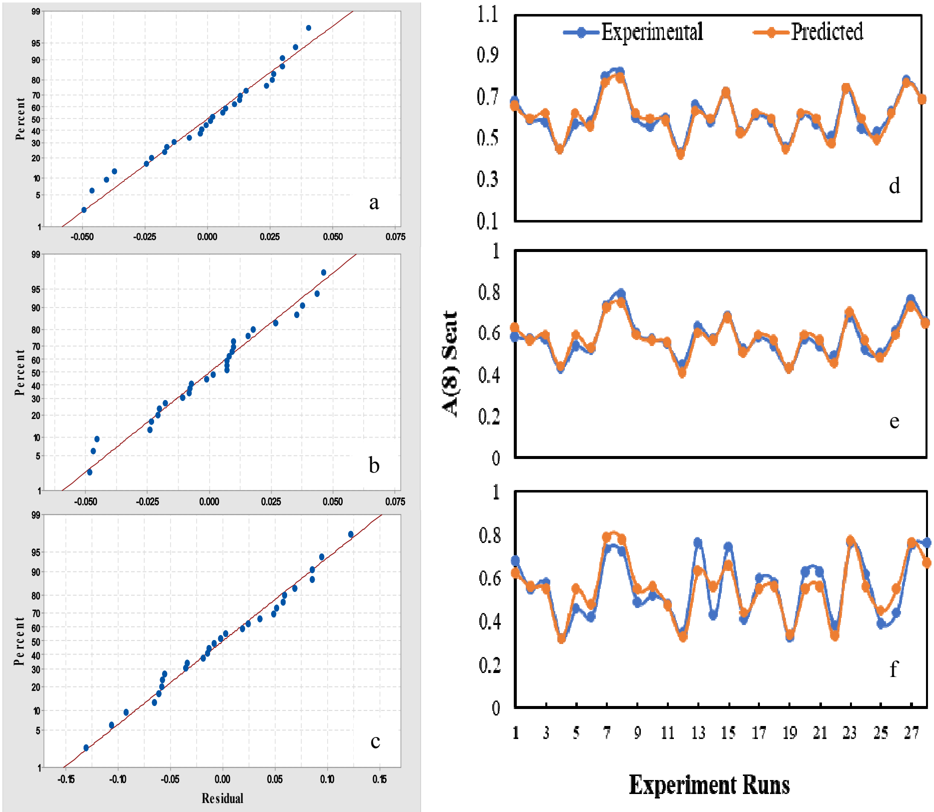
Table 8 ANOVA analysis (continued)

						TD2					
	A (8)- Seat (y_3)					*A_{wz}-Floor (y_4)*					
Model	3	0.207	0.069	93.460	0.000*	3	0.136	0.045	32.550	0.000*	3
Linear	3	0.207	0.069	93.460	0.000	3	0.136	0.045	32.550	0.000	3
Speed (m/s)	1	0.191	0.191	258.960	0.000*	1	0.124	0.124	89.280	0.000*	1
Road IRI (m/km)	1	0.011	0.011	14.260	0.001*	1	0.010	0.010	7.130	0.013*	1
Posture	1	0.005	0.005	7.150	0.013*	1	0.002	0.002	1.230	0.278	1
Error	24	0.018	0.001			24	0.033	0.001			24
Lack-of-Fit	14	0.012	0.001	1.650	0.215	14	0.031	0.002	7.620	0.001*	14
Pure Error	10	0.005	0.001			10	0.003	0.000			10
Total	27	0.224				27	0.169				27
						TD3					
	A (8)- Seat (y_5)					*A_{wz}-Floor (y_6)*					
Model	3	0.468	0.156	32.370	0.000*	3	0.145	0.048	28.300	0.000*	3
Linear	3	0.468	0.156	32.370	0.000	3	0.145	0.048	28.300	0.000	3
Speed (m/s)	1	0.421	0.421	87.310	0.000*	1	0.124	0.124	72.610	0.000*	1
Road IRI (m/km)	1	0.047	0.047	9.700	0.005*	1	0.018	0.018	10.670	0.003*	1
Posture	1	0.001	0.001	0.110	0.741	1	0.003	0.003	1.630	0.214	1
Error	24	0.116	0.005			24	0.041	0.002			24
Lack-of-Fit	14	0.056	0.004	0.680	0.756	14	0.037	0.003	7.100	0.002*	14
Pure Error	10	0.059	0.006			10	0.004	0.000			10
Total	27	0.584				27	0.186				27

*Significant; Significant at 95% confidence level ($p \leq 0.05$).

Figure 3(a)–(c) represent the normal plots of residual, and Figure 3(d)–(f) represent the experimental and predicted responses for the Y1, Y3, and Y5. Similarly, for Y2, Y4, and Y6 responses, the residual plots are shown in Figure 4(a)–(c), and experimental vs. predicted responses are shown in Figure 4(d)–(f). The model successfully captured the correlation between the actual vs. predicted response because the values were very close to each other. It was found that most of the values of daily vibration dose for all the selected drivers were above the exposure action value (EAV) as shown in Figure 3(d)–(f)) as per ISO 2631-1 (1997).

Figure 3 Residual plots (a)–(c) and experimental vs. predicted response and (d)–(f) on a seat for TD1, TD2, and TD3 (see online version for colours)

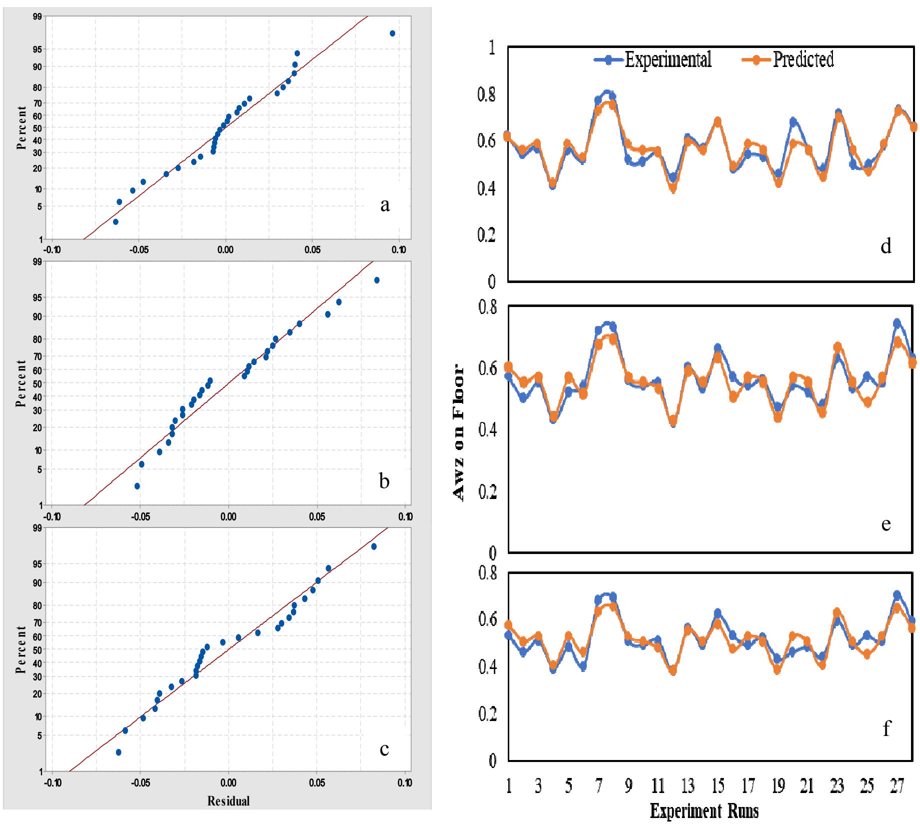


3.2.1 Analysis of response surface

To minimise the A(8) values on the seat and A_{wz} on the floor, 2D and 3D plots were generated. It reveals that A(8) and A_{wz} values were increasing with increasing the tractor speed and road IRI, which was in line with Mehta et al. (1997) who also reported increased vibration accelerations with increasing speed. Furthermore, a few researchers also reported high vibrations produced due to surface irregularities in road pavement (Agostinacchio et al., 2014; Reina and Rose, 2016; Sekulić, 2020). This rise in speed reduces driver travel comfort, which further affects their work performance (Sam and Kathirvel, 2006). Therefore, the tractor needs significant optimum input parameters to make the ride comfortable for drivers. The minimum observed values of A(8) on seat 0.43, 0.41, 0.43 m/s^2 and A_{wz} on floor values were 0.42, 0.32, 0.38 m/s^2 for the selected tractor drivers 1, 2, and 3 respectively.

The influence of the speed and road IRI was observed on the A(8) as reflected by a more steep 3D surface chart and dense counter line (Long et al., 2019). 3D surface graphs were plotted to represent the relationship among the three different parameters. Contour plots represent the different ranges with different colour bands in a single chart. For the first driver, 3D response surface plots were shown in Figure 5(a)–(c), and contour plots were shown in Figure 5(b) and (d). In Figure 5(a)–(c), it was observed that A(8) and A_{wz} increase slightly with an increase in speed and road IRI. In Figure 5(b) and (d), the contour plots reflect the highest value of A(8), and A_{wz} was observed with the highest level of IRI and speed. The A(8) was found minimum at road IRI ≤ 4.0 m/kg and speed ≤ 7.3 m/s. Similarly, minimum A_{wz} was found near road IRI ≤ 4.5 m/km and at a speed of less than 8 m/s.

Figure 4 Residual plots (a)–(c) and experimental vs. predicted response (d)–(f) on the floor for TD1, TD2, and TD3 (see online version for colours)



And for the second driver, 3D surface plots and contour plots were shown in Figure 6(a)–(d). From Figure 6(a)–(c), it was observed A(8) was increased with increasing the speed and road IRI. Minimum A(8) was found <0.45 m/s^2 on the ≤7.3 m/s speed and ≤3.25 m/km road IRI from Figure 6 (b). And minimum A_{wz} was found <0.45 m/s^2 on the speed ≤6.5 m/s and ≤2.8 m/km road IRI in Figure 6(d).

Figure 5 A 3D and contour plots of the effect of speed and road IRI on A(8) and A_{wz} for the TD1 (see online version for colours)

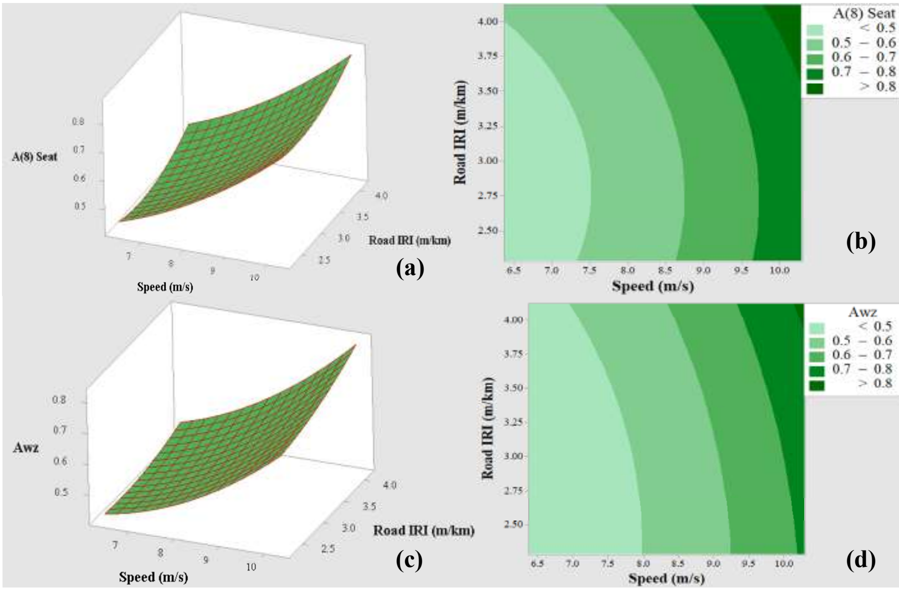
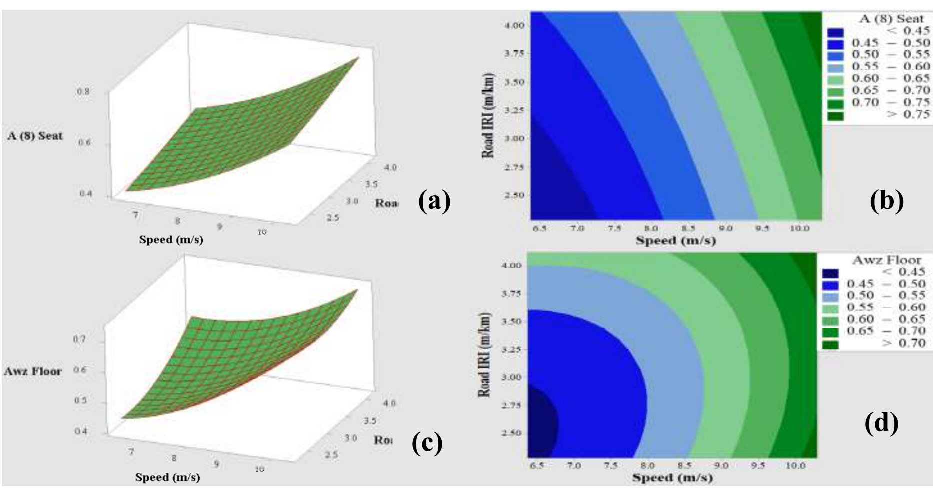
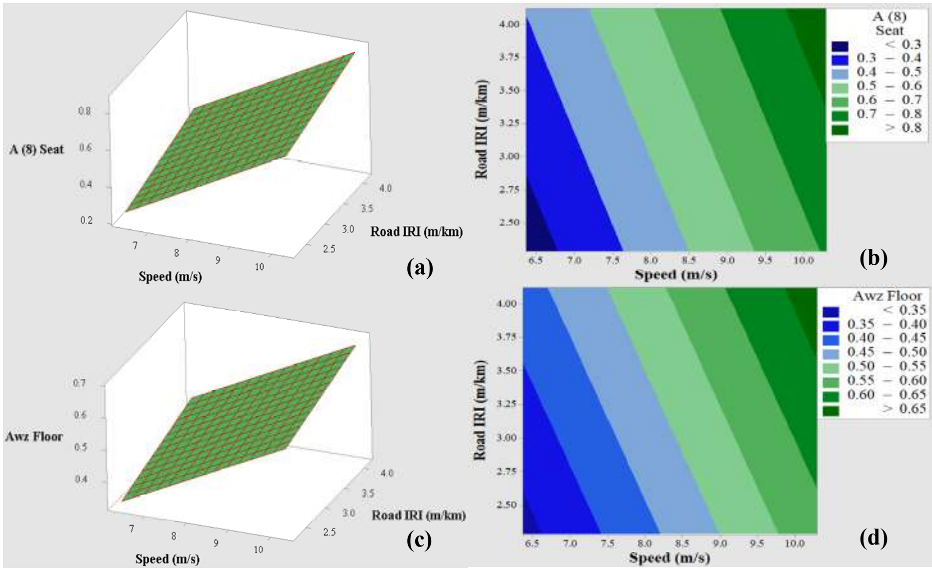


Figure 6 A 3D and contour plots of the effect of speed and road IRI on A(8) and A_{wz} for the TD2 (see online version for colours)



For the third driver, 3D surface plots and contour plots are shown in Figure 7(a)–(d). From Figure 7(a)–(c), it is observed A(8) was sharply increased with increasing the speed and road IRI. The minimum A(8) was found <0.3 m/s^2 on the ≤6.8 m/s speed and ≤2.8 m/km road IRI from Figure 7(b). And minimum A_{wz} was found <0.35 m/s^2 on the speed ≤6.6 m/km and ≤2.8 m/km road IRI in Figure 7(d). It was stated that the WBV response was increasing with increasing speed (Mayton et al., 2014). Scarlett et al. (2007) stated that the WBV was dependent on surface irregularities (roughness) conditions (Scarlett et al., 2007).

Figure 7 A 3D and contour plots of the effect of speed and road IRI on A(8) and A_{wz} for the TD3 (see online version for colours)



Among these interactions for all the selected drivers, it was clear that the input parameters have a strong impact on the output parameters, which were also found to be significant input parameters in the statistical ANOVA test (Scarlett et al., 2007). Due to the vibration being high and imbalance, misalignment, wear, and looseness in a tractor. It was observed that the minimum A(8) on the seat and A_{wz} on the floor were found on the third driver among all the selected drivers. Overall, the optimum speed value was found at 6.37 m/s^2 and the road IRI was 3.2 m/km.

3.2.2 Optimisation and desirability

In addition, for each input parameter, the optimisation was carried out using a desirability function. It was performed to figure out how well a factor meets the goal for the output response. There were two ways to assess the effectiveness of an optimisation strategy: individual desirability (d) and composite desirability (D). Desirability ranges should be between 0–1 (Amdoun et al., 2018);1 represents the ideal condition; zero implies that one or more responses were beyond their permissible limits. In this study, the composite desirability (D) was 0.9773, 0.9757, and 0.9872 for drivers first, second, and third which was very close to 1. Moreover, the individual desirability indicates that settings would be more effective for daily doses on a tractor seat (d:0.99173, 0.96033, 0.98420). The optimum parameters (speed 6.3687 m/s^2, road IRI 2.2808 m/km with P2) were the best experiment combination for all the selected drivers.

3.2.3 Validation experiments

For confirmation of the results, yet again real-time experimentation has been carried out to acquire the optimum levels of input parameters that leads to reduce the A(8) on the seat and A_{wz} on the floor. It was noted that the optimised levels were speed 6.3687 m/s^2, road IRI 2.2808 m/km, and the second category of the posture was taken among all the selected tractor drivers. A total of five trials have been done by taking the optimum level of input parameters as mentioned in Table 9.

Table 9 The confirmatory experiment runs w.r.t optimised input conditions

Trial no.	*Speed* (m/s)	*Road IRI* (m/km)	*TD1*				*TD2*			*TD3*		
			Posture	*A(8)*	A_{wz}	*VDR*	*A(8)*	A_{wz}	*VDR*	*A(8)*	A_{wz}	*VDR*
1	6.37	2.28	P2 (FSWB)	0.43	0.42	102.38	0.40	0.41	97.56	0.36	0.38	94.74
2	6.37	2.28	P2 (FSWB)	0.42	0.39	107.69	0.43	0.44	97.73	0.35	0.34	102.94
3	6.37	2.28	P2 (FSWB)	0.41	0.43	95.35	0.43	0.41	104.88	0.35	0.34	102.94
4	6.37	2.28	P2 (FSWB)	0.40	0.43	93.02	0.39	0.40	97.50	0.33	0.37	89.19
5	6.37	2.28	P2 (FSWB)	0.43	0.46	93.48	0.41	0.41	100.00	0.36	0.35	102.86

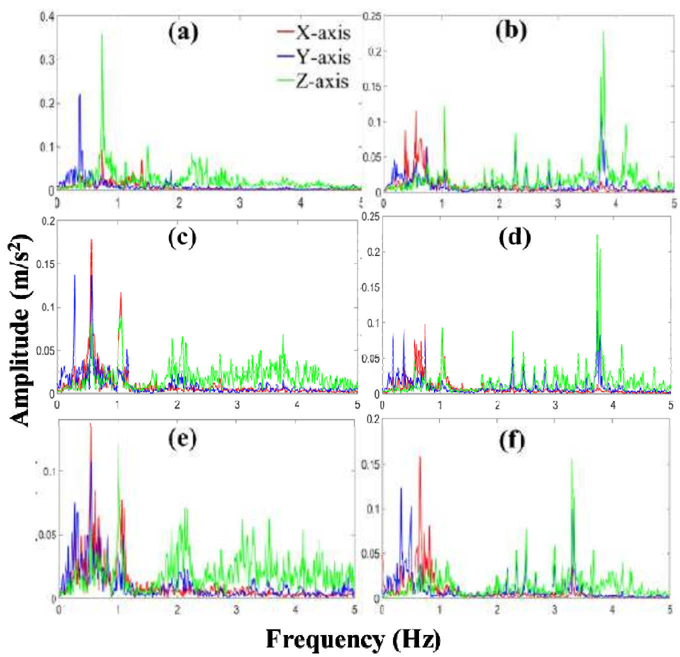
The results of the confirmatory experiment were within the 95% confidence interval (CI) of the predicted responses under the optimal input circumstances, indicating that the model was correct. As a result, the optimised input conditions have been verified and can be implemented in a real-world application.

3.3 FFT analysis

In this study, the raw seat pan acceleration data were analysed at a seat along the *x*, y, and *z* axes to find out the dominant frequencies wrt selected posture. The total number of experiments was 28, for FFT analysis was done by taking the means of 14 experiments for P1 and P2 for each driver. From Figure 8, it was observed that the dominant frequencies were found on the z-axis. During the analysis, it was observed that the FFT response was the same for all the experiment runs with slight variations. Moreover, the peaks of frequency response vary wrt the selected posture.

Above Figure 8(a)–(f) were categorised posture-wise by taking the means of raw data for selected tractor drivers. In the frequency spectra, it can be seen that there were various frequency peaks along the translational axes, indicating that the vibration energies change dependency along with different frequency ranges (Muzammil et al., 2004). The frequency response wrt P1 and P2 of driver one is shown in Figure 8(a)–(b), for the second driver shown in Figure 8(c) and (d), and for driver third, the frequency response shown in Figure 8(e) and (f). The above-given Figure 8(a), (c) and (e) indicates the low-frequency vibration occurred between 0–1.15 Hz on the tractor seat. In contrast, the dominant peak was found between 0.5–0.72 Hz. Moreover, in Figure 8(b), (d) and (f) the decisively higher peaks were found between 3–4 Hz on the tractor floor. Consequently, the frequencies were varied concerning the selected posture. These frequencies were critical for the driver and may cause discomfort or other health effects on human health due to long-duration exposure to low-frequency vibration. The frequency domain is closely related to riding comfort, it demonstrates the ground deformability and enhances vibration isolation (Reina et al., 2018).

Figure 8 Fast Fourier transform (FFT) response analysis (see online version for colours)



4 Conclusions

The HGCZs were examined to analyse the comfort reaction among selected drivers. Total vibration (a_v) was evaluated, varying from 0.62–1 m/s^2, 0.6–0.94 m/s^2, and 0.49–0.9 m/s^2 for tractor drivers 1, 2, and 3 respectively. As per ISO 2631-1 (1997), the tractor driver's total vibration dose varies under the 0.5-1 m/s^2 category, and the comfort reaction was fairly uncomfortable. Furthermore, overall daily vibration exposure A(8) among selected tractor drivers was found above the recommended values as per ISO 2631-1 (1997) and Directive2002/44/EU. As well as the transmission of WBV was dominant in the z-axis. In addition, the average speed and road IRI were found to have a significant influence on the output parameters at a 95% ($p \leq 0.05$) confidence level. Consequently, minimum speed and minimum road IRI could lead to better ride conditions. The correlation between experimental and predictive responses was better by using the RSM regression model with the nominal mean error. Moreover, the composite desirability (D) was found 0.9773 and 0.9757 for drivers 1 and 2, respectively which was very close to 1. It was also found that WBV has a direct correlation with the different BMI categories as the value of WBV decreases with the BMI of the driver increases. This suggests that the settings appear to achieve optimum results for all responses. In the confirmatory experiment, it was found that the responses were within a 95% confidence interval of the predictive responses with the optimised input parameter conditions. Minimum weighted acceleration can be achieved by determining optimal input parameters, but design modifications to tractor components like the seat and suspension system were needed to bring pain levels down to acceptable levels.

5 Future implications/limitations of the study

- This study was limited to three categories of BMI. In future work, more subjects can be taken to generalise the results.
- The conclusions of this study may only apply to one kind of tractor in the lack of a generalised verified model. To verify the simulation model, authors may choose from a variety of tractors with varying engines, suspensions, and tyres. Further study can be extended to study the influence of varying tyre inflation pressure, different engines, suspensions, tyres, cushions, etc.
- The total amount of the vibration arising from the different sources can be taken for further study.
- This study was limited to only five types of roads, but the road conditions may vary from poor to good conditions (Wang et al., 2020). Further study investigate on the other road conditions for generalised results.

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Appendix 1: Full factorial design and corresponding responses

	Experimental factors			*Response factors for TD1*			*Response factors for TD2*			*Response factors for TD3*		
Trial no.	*Speed* (m/s)	*Road IRI* (m/km)	*Posture*	*A (8) Seat*	A_{wz} *Floor*	*VDR*	*A (8) Seat*	A_{wz} *Floor*	*VDR*	*A (8) Seat*	A_{wz} *Floor*	*VDR*
1	8.33	4.12	VEWB	0.68	0.62	110.37	0.58	0.57	101.39	0.68	0.53	109.74
2	8.33	3.20	FSWB	0.59	0.54	109.02	0.57	0.50	113.29	0.55	0.46	107.11
3	8.33	3.20	VEWB	0.58	0.57	101.75	0.57	0.55	103.46	0.58	0.51	105.50
4	6.37	3.20	VEWB	0.45	0.41	108.47	0.43	0.43	100.00	0.32	0.39	108.23
5	8.33	3.20	VEWB	0.57	0.56	102.51	0.54	0.52	105.03	0.46	0.48	114.88
6	8.33	2.28	FSWB	0.58	0.52	111.45	0.52	0.54	95.92	0.42	0.40	110.78
7	10.30	3.20	FSWB	0.80	0.77	103.64	0.73	0.72	101.39	0.73	0.68	96.76
8	10.30	3.20	VEWB	0.82	0.79	104.04	0.79	0.73	108.79	0.72	0.69	96.65
9	8.33	3.20	VEWB	0.60	0.52	113.93	0.60	0.56	107.90	0.49	0.51	113.33
10	8.33	3.20	FSWB	0.56	0.51	109.65	0.57	0.54	106.52	0.52	0.49	100.20
11	8.33	2.28	VEWB	0.60	0.55	109.32	0.55	0.55	99.82	0.48	0.51	111.02
12	6.37	3.20	FSWB	0.43	0.44	98.62	0.45	0.42	108.37	0.35	0.38	94.97
13	8.33	4.12	FSWB	0.66	0.61	108.60	0.63	0.60	104.67	0.76	0.56	106.26
14	8.33	3.20	FSWB	0.58	0.57	102.29	0.57	0.53	108.35	0.43	0.49	109.65
15	9.72	2.55	VEWB	0.72	0.68	106.16	0.68	0.66	104.11	0.74	0.62	105.83
16	6.94	3.85	VEWB	0.53	0.48	108.88	0.52	0.57	90.67	0.41	0.53	80.30
17	8.33	3.20	VEWB	0.61	0.54	114.13	0.58	0.54	108.75	0.60	0.49	111.16
18	8.33	3.20	FSWB	0.58	0.53	109.49	0.54	0.56	96.09	0.58	0.52	109.00
19	6.94	2.55	FSWB	0.46	0.46	101.09	0.43	0.47	91.65	0.33	0.43	92.97
20	8.33	3.20	VEWB	0.61	0.68	88.71	0.57	0.54	106.33	0.63	0.46	125.05
21	8.33	3.20	FSWB	0.57	0.56	102.51	0.54	0.52	104.62	0.63	0.48	119.42
22	6.94	2.55	VEWB	0.51	0.48	107.53	0.49	0.48	102.93	0.38	0.44	102.74
23	9.72	3.85	FSWB	0.74	0.72	103.21	0.68	0.63	108.61	0.76	0.59	104.43
24	8.33	3.20	FSWB	0.55	0.50	110.04	0.52	0.53	98.10	0.62	0.49	122.59
25	6.94	3.85	FSWB	0.53	0.50	107.24	0.50	0.57	86.76	0.39	0.53	65.17
26	8.33	3.20	VEWB	0.63	0.58	109.15	0.61	0.55	110.77	0.44	0.51	123.43
27	9.72	3.85	VEWB	0.78	0.73	106.54	0.76	0.74	103.52	0.75	0.70	84.96
28	9.72	2.55	FSWB	0.69	0.66	105.33	0.65	0.63	103.34	0.76	0.59	108.50

Appendix 2: Selected design and weighted acceleration on a seat

	Experimental Factors			*TD1*			*TD2*			*TD3*		
Trial no.	*Speed* (m/s)	*Road IRI* (m/km)	*Posture*	a_x	a_y	a_z	a_x	a_y	a_z	a_x	a_y	a_z
1	8.33	4.12	VEWB	0.357	0.1258	0.68	0.3282	0.2077	0.58	0.152	0.1121	0.59
2	8.33	3.20	FSWB	0.278	0.1381	0.59	0.2552	0.2944	0.57	0.2963	0.1149	0.5
3	8.33	3.20	VEWB	0.262	0.1583	0.58	0.2894	0.2654	0.57	0.3408	0.1516	0.54
4	6.37	3.20	VEWB	0.254	0.1178	0.45	0.2237	0.2911	0.43	0.2454	0.1113	0.42
5	8.33	3.20	VEWB	0.325	0.1534	0.57	0.2277	0.2389	0.54	0.3125	0.155	0.55
6	8.33	2.28	FSWB	0.308	0.1649	0.58	0.2887	0.2711	0.52	0.304	0.1271	0.44
7	10.30	3.20	FSWB	0.319	0.1265	0.8	0.3399	0.2053	0.73	0.2496	0.1093	0.66
8	10.30	3.20	VEWB	0.294	0.1592	0.82	0.3236	0.157	0.79	0.2411	0.113	0.66
9	8.33	3.20	VEWB	0.235	0.1842	0.6	0.216	0.1808	0.6	0.3626	0.1524	0.58
10	8.33	3.20	FSWB	0.211	0.1555	0.56	0.2261	0.2797	0.57	0.2153	0.1571	0.49
11	8.33	2.28	VEWB	0.231	0.1526	0.6	0.3686	0.3134	0.55	0.2975	0.1347	0.56
12	6.37	3.20	FSWB	0.321	0.1473	0.43	0.2532	0.1701	0.45	0.2327	0.1058	0.36
13	8.33	4.12	FSWB	0.331	0.1912	0.66	0.3532	0.261	0.63	0.2282	0.1045	0.59
14	8.33	3.20	FSWB	0.297	0.1562	0.58	0.2424	0.2868	0.57	0.3121	0.1495	0.53
15	9.72	2.55	VEWB	0.284	0.1535	0.72	0.3769	0.2807	0.68	0.3165	0.1105	0.65
16	6.94	3.85	VEWB	0.319	0.1596	0.53	0.2576	0.2592	0.52	0.2825	0.1574	0.42
17	8.33	3.20	VEWB	0.277	0.1354	0.61	0.2819	0.1525	0.58	0.2358	0.1235	0.55
18	8.33	3.20	FSWB	0.324	0.1656	0.58	0.2655	0.2943	0.54	0.352	0.1181	0.57
19	6.94	2.55	FSWB	0.318	0.1861	0.46	0.2925	0.2297	0.43	0.3447	0.1399	0.4
20	8.33	3.20	VEWB	0.267	0.1182	0.61	0.3645	0.1836	0.57	0.3183	0.1507	0.58
21	8.33	3.20	FSWB	0.279	0.1532	0.57	0.3741	0.1636	0.54	0.2807	0.1385	0.57
22	6.94	2.55	VEWB	0.384	0.1315	0.51	0.3152	0.2311	0.49	0.3488	0.1142	0.45
23	9.72	3.85	FSWB	0.297	0.1482	0.74	0.3569	0.2044	0.68	0.2455	0.1421	0.61
24	8.33	3.20	FSWB	0.314	0.138	0.55	0.3276	0.1401	0.52	0.2761	0.103	0.6
25	6.94	3.85	FSWB	0.362	0.1109	0.53	0.2563	0.1924	0.5	0.3749	0.1055	0.35
26	8.33	3.20	VEWB	0.351	0.1858	0.63	0.3205	0.2608	0.61	0.3523	0.1222	0.63
27	9.72	3.85	VEWB	0.291	0.1582	0.78	0.3733	0.2787	0.76	0.2167	0.1413	0.59
28	9.72	2.55	FSWB	0.352	0.1924	0.69	0.2926	0.1524	0.65	0.3204	0.1209	0.64

Appendix 3: Total acceleration values, exposure action, and limit values

Trial no.	Experimental factors			TD1			TD2			TD3		
	Speed (m/s)	Road IRI (m/km)	Posture	a_v	T_u	T_l	a_v	T_u	T_l	a_v	T_u	T_l
1	8.33	4.12	VEWB	0.8	9.49	2.37	0.86	8.07	2.02	0.73	11.16	2.79
2	8.33	3.20	FSWB	0.79	9.64	2.41	0.73	11.17	2.79	0.71	12.02	3.00
3	8.33	3.20	VEWB	0.79	9.57	2.39	0.72	11.54	2.88	0.78	9.78	2.44
4	6.37	3.20	VEWB	0.67	13.36	3.34	0.6	16.85	4.21	0.49	24.71	6.18
5	8.33	3.20	VEWB	0.71	11.88	2.97	0.76	10.38	2.59	0.67	13.44	3.36
6	8.33	2.28	FSWB	0.76	10.38	2.6	0.76	10.42	2.61	0.62	15.58	3.90
7	10.30	3.20	FSWB	0.92	7.13	1.78	0.93	6.89	1.72	0.82	8.94	2.23
8	10.30	3.20	VEWB	0.94	6.84	1.71	0.94	6.73	1.68	0.81	9.15	2.29
9	8.33	3.20	VEWB	0.72	11.64	2.91	0.73	11.22	2.81	0.74	10.98	2.75
10	8.33	3.20	FSWB	0.76	10.37	2.59	0.67	13.39	3.35	0.64	14.54	3.63
11	8.33	2.28	VEWB	0.87	7.88	1.97	0.71	11.76	2.94	0.66	13.80	3.45
12	6.37	3.20	FSWB	0.62	15.59	3.9	0.66	13.97	3.49	0.50	23.81	5.95
13	8.33	4.12	FSWB	0.88	7.74	1.94	0.85	8.31	2.08	0.83	8.63	2.16
14	8.33	3.20	FSWB	0.78	9.98	2.49	0.75	10.77	2.69	0.65	14.42	3.60
15	9.72	2.55	VEWB	0.95	6.7	1.68	0.85	8.3	2.08	0.88	7.78	1.95
16	6.94	3.85	VEWB	0.73	11.28	2.82	0.73	11.31	2.83	0.61	16.26	4.06
17	8.33	3.20	VEWB	0.73	11.16	2.79	0.75	10.74	2.69	0.70	12.11	3.03
18	8.33	3.20	FSWB	0.77	10.01	2.5	0.77	10.07	2.52	0.78	9.97	2.49
19	6.94	2.55	FSWB	0.68	13.16	3.29	0.69	12.56	3.14	0.62	15.84	3.96
20	8.33	3.20	VEWB	0.81	9.21	2.3	0.73	11.13	2.78	0.80	9.30	2.33
21	8.33	3.20	FSWB	0.79	9.7	2.43	0.72	11.46	2.87	0.76	10.28	2.57
22	6.94	2.55	VEWB	0.73	11.12	2.78	0.76	10.29	2.57	0.64	14.58	3.65
23	9.72	3.85	FSWB	0.89	7.56	1.89	0.87	7.86	1.96	0.86	8.18	2.04
24	8.33	3.20	FSWB	0.72	11.56	2.89	0.73	11.26	2.81	0.74	10.94	2.74
25	6.94	3.85	FSWB	0.67	13.29	3.32	0.75	10.68	2.67	0.67	13.33	3.33
26	8.33	3.20	VEWB	0.84	8.49	2.12	0.84	8.5	2.12	0.68	12.82	3.21
27	9.72	3.85	VEWB	1	5.98	1.5	0.91	7.29	1.82	0.83	8.72	2.18
28	9.72	2.55	FSWB	0.8	9.44	2.36	0.89	7.58	1.9	0.90	7.43	1.86