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`Prediction of the overall sound level of diesel engine with bioethanol & diesel blend fuelsby help of back-propagation error algorithm

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Abstract

In Iran, MF399 tractors are widely used for farming. The trend toward blending renewable fuels like biodiesel, bioethanol, and biomethanol with diesel fuel has risen in recent years due to the scarcity of fossil fuels and environmental concerns. The usage of bioethanol fuel in a tractor engine was analyzed and compared to the noise of diesel fuel because of the significance of noise and its influence on the driver's mental, other pass-by people's, and physical health on the job. Predicting the MF399 tractor's noise level using artificial neural networks is the focus of this research. The location was ready for the test inAs reported by the global norms and communication released by the car were taken, and finally, average decibel readings in the frequency domain. The findings demonstrated that the multi-layer Perceptron support system network Overall system noise prediction using a propagation error technique with two hidden layers and, specifically, three neurons in the first hidden layer and two neurons in the second hidden layer.input from the car's engine speed affects the location of persons passing the vehicle from a different angle.adaptable to a wide range of conditions and fuel combinations

Keywords: "Noise, Diesel Engines, Artificial Neural Networks, Multi-Layer Perceptron, Back Propagation (Error) Algorithm".

1. Introduction

Diesel engines, which utilise a compression ignition system, have seen widespread usage throughout human history. Engines are widely used in several fields, including agriculture, transportation, manufacturing, submarines, thermal power plants, and automobiles. Diesel engines are superior than gasoline engines in terms of thermal efficiency, fuel savings, consumer expenditure, and engine lifespan, however they are in jeopardy due to noise pollution. Unwanted sound, or noise, is widely recognized as one of the most significant physically detrimental causes. Many issues arise for both the driver and the environment as a result of them. Excessive noise levels have been linked to a variety of health problems, including hearing loss, hypertension, headaches, weariness, and irritable or furious drivers (Rothet al. 1991; Hassan-Beygiet al. 2005; Crocker et al. Noise is defined as any audible sound that is distracting to the listener. For the purposes of this study, we will use the definition of noise as any sound that is sufficiently loud that it causes audible discomfort to the listener. It doesn't matter whether the noise is pleasant or unpleasant (Anonymous, 1996).

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NIOSH2 rules (Anonymous,1996) are only one example of a set of international regulations enacted by several organizations to restrict working hours in hazardous environments. A noise dosage is defined as 8 hours of exposure to noise at 85 dB (A) or more per day, or 4 hours of exposure to noise at 88 dB (A) or more per day (Irwin et al., 1979; Crocker et al., 1998). Tractor drivers without cabins or with open windows in their cabins may experience noise levels in excess of 95 dB (A) at the driver's ear location (Dennis et al., 1995; Broste et al., 1989). Most current tractors produce noise in excess of 90 dB (A), while other agricultural machinery, including auto-combines, corn harvest machines, hammer mills, and dryers, produce noise in excess of 100 dB (A) (Bean et al., 1995). The majority of tractor drivers aged 20 and older suffered some degree of hearing loss, with 34% experiencing severe hearing loss (Crocker et al., 1993). Hearing loss was reported by around 56% of the studied tractor drivers, or about 20 dB (A) less than the same age control group, with the majority of cases occurring in drivers over the age of 30 (Solecki,1965 Solecki,1965). Hasan Beigi et al. Bidgoli conducted the study, which included the use of an artificial neural network to foretell the noise produced by a 13-horsepower power tiller. Sound signals emitted by the vehicle were monitored, and global noise level values were calculated in the frequency domain after the test site was set up in accordance with international regulations. Predicting vehicle noise at the driver's ear position using a multi-layer perceptron network with a back propagation error algorithm, two hidden layers, three neurons in the first hidden layer, and two neurons in the second hidden layer (Hassan-Beygiet al., 2005) was found to be affected by engine speed input variables, gear ratio, and suitable surface type. Research conducted by Guangzhou Poe et al. on an eight-cylinder diesel engine installed in a military vehicle found that engine noise significantly increased when revved from 1800 to 1900. However, there is not much of an increase in engine noise from 1900 to 2200 rpm. The intake and exhaust systems make more noise between 1900 and 2200 rpm. About 120 decibels of noise may be heard close to the air intake and exhaust pipe (Guangpul et al., 2006).

The purpose of this study is to use artificial neural networks to analyze the noise level of an MF399 tractor at other pass-by people positions in light of the aforementioned discussions and the need to begin research and acquire technical knowledge of producing biofuels in Iran in order to replace these fuels with fossil fuels and the need to analyze noise caused by the fuel blends on engine. Artificial neural networks may be seen as a viable option for accurately estimating the degree of noise. The findings of such a research would aid in the development and execution of measures for the safety of the driver and passengers, such as the selection of suitable values for the examined parameters to generate less noise than the 85dB(A) requirement.

2. Materials and Methods

2.1 Testing tractor

In this project the impact of the integration of diesel fuel and bioethanol on engine noise were examined. The data from four-stroke, 6-cylinder engine noise of MF399 tractor that is made in Tabriz Tractor Manufacturing Plant, measured, recorded and were analyzed. Engine specifications are presented in Table 1.

Table1-Technical specifications ofMF399tractorengine.

Model	Perkins A63544
Manufacturer	Iran Tractor ManufacturingCompany
Number of cylinders	6
Cylinderstroke	127mm
diameter ofthe cylinder	98.6mm
Volume ofcylinder	5.8Lit
combustion	1,5.3,6,2,4
maximumpower at 2300 rpm	(82kw)110 hp

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376 N.m	Maximumtorqueat 1300 rpm

2.2 Tools and measurement equipment

A microphone was used to measure the noise. To the other pass-by people position, the microphone situated 1.2 metres above ground level at a distance of 7.5 metres from the path of the tractor's centre line. Microphone was placed horizontally balanced. To obtain noise signals of different treatments, an audio device of HT157 model was used (fig.1). The device is designed for measuring the sound pressure level (SPL) from 25 dB to 140 dB with a frequency in the range of 10 Hz to 20 kHz. Recorded sound waves are available both in analyzed and raw fo m. AC output voltage device is analog which is compatible with input signal (in dB). The device is portable and has a microphone and calibrator device. Noise omission for measuring device is done using the same calibrator. Noise signal at 5 engine speeds obtained in MF399 tractor (1700,1800, 1900, 2000 and 2100 rpm) for different fuel mixtures. Dynamometer was used to change the applied charge and spin on the engine. Dynamometer (NJ-FROMENT Σ5) was used by the british company(fig.2). The dynamometer through a magnetic field is applied, the amount of power and torque to automatically measure.All experiments were performed in all cases with four repetition.

2.3 Characteristics of the test site

The optimal location for the experiment was chosen based on ISO (International Organization for Standardization) norms Anonymous (1996) and the Automotive Industry Benchmark (2009). The area was a wide-open region devoid of obstacles like trees, soil, or buildings. Measurements were not taken in the presence of rain or lightning, and the ambient noise level was kept at least 10 decibels lower than the lowest sound level recorded during testing (Anonymous, 2009). In terms of size,

the area is shown in Figure 3.

Figure(1) Soundmeasuring devicesused inthisresearch.

Figure(2) Dynamometerused inthisstudy.

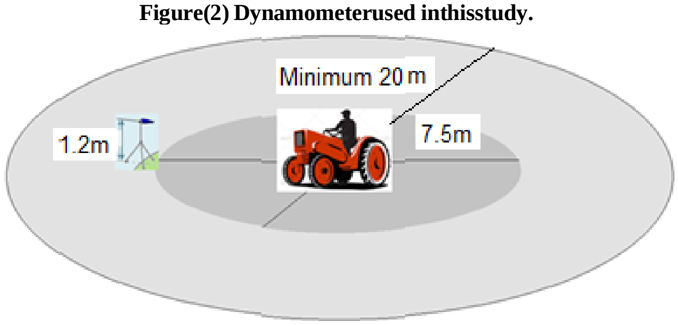
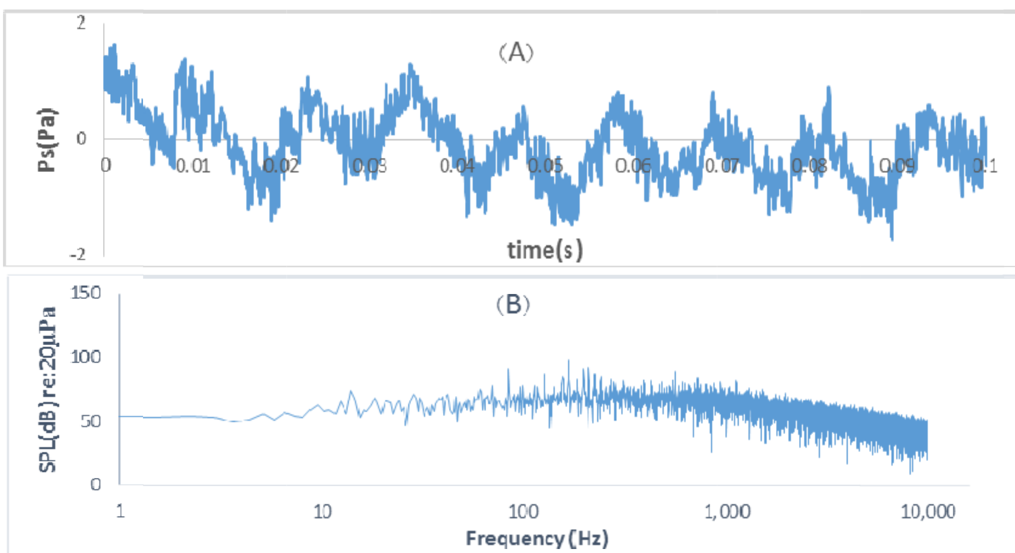


Figure (3) Size of the intended area for testing.

2.4 Data capture and data processing method

Experiments were performed in stationary mode on a selected MF399 tractor engine. The independent variables in this study consisted of a mixture of seven different fuels (E0, E2, E4, E6, E8, E10 and E12) and 5 levels of engine speed (1700,1800,1900, 2000 and 2100 rpm). After setting the desired values of the independent parameters (inputs), such as engine speed and the amount of combination of diesel fuel and bioethanol were tested on the engine of MF399tractor. The sound of the engine has been stored with the microphone for 20 seconds.Then

the raw and analyzed audio signals were given and recorded in a computer via a USB. The engine used in this study was a 6-cylinder, four-stroke engine. The rate of sampling data according to the Nyquist measurement, was required to beat least two times the maximum frequency, to allow the conversion of analog output signals of sound meter device to be correct (Dennis *et all*., 1995) therefore, given the range of human hearing, the rate of sampling is considered 48,000 Hz. Then the digital signals will be stored on a computer hard disk using portable computer sound card, and installed CoolEdit 2000 software. Figure 4-A shows a sample of the audio signal in the time domain, but since the inspection and analyzing the emitted sound signals in time domain will determine limited information and considering the fact that the response of the ear and sense of sound in human depends highly on the frequency so it's necessary for sound signals in the time domain to be converted to the frequency domain until the frequency content of the sound signals are obtained (Crocker *et al.*, 1993). To convert time domain signals into the frequency domain, Fast Fourier Transform (FFT) method was used. Thus, a computer program was written to do this work and the frequency domain obtained using the narrow band noise spectrum. Figure 4-B shows an example of a sound signal in the frequency domain. By adding a sub computer program, frequency domain narrow band sound signals were converted to an overall sound level values.



Figure(4) A- noise signals in time domain, B- spectrum of the narrow-band sound pressure level at the driver's position, the speed 1700 rpm, and fuel composition E12.

1.Artificial Neural Networks

An artificial neural network consists of a number of neurons that are located together in a certain way. Neurons are located in layers and the network includes multiple neuron in the input layer, one or more neurons in theoutput layer and neurons in hidden layer or layers. Most artificial neural network algorithms and architectures alters by a change in the neuron model, and the connections between neurons that are used and applied weights between neurons. The most common type of artificial neural network, include feedforward, feedback and competitive (Fausett, 1993). In this study, feed forward neural networks were used. This type of neural network is mainly used for function approximation and models classification. Multi-layer Perceptron Network (MLP), is the most common feedforward network. The network consists of an input layer, one or more hidden layers and an output layer. To train the network, back-propagation error learning algorithm was used in which the process of applying this method is the following (Jam et all., 2000؛ Khanna, 1990) (A)- weight matrix randomly assigned to each of the connections (B)- Selecting the input vector and the corresponding output vector. (C)- Computing the outputs of the neurons in each layer and thus calculating the output neurons in the output layer D)- Weight update using back-propagation error method (E)- evaluating the performance of the trained network with the help of root mean square error (RMSE) and finally back to of section c and the end of the training.

1.1 Artificial neural network topology

To calculate the overall sound level, training and evaluation of artificial neural networks, two different inputs including engine speed, and combinations of fuels were used. According to the conditions described in the

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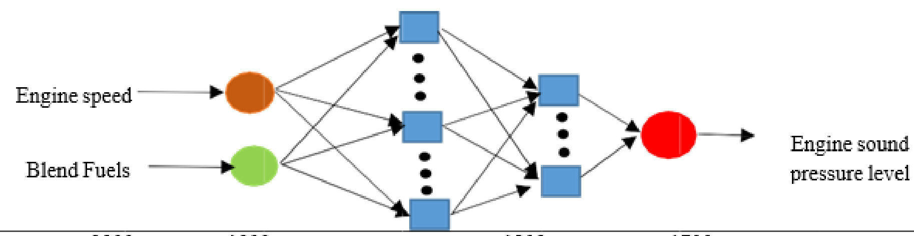
previous section, artificial neural network with two neurons in the input layer (engine speed, various fuel blends) and an output layer neuron (overall sound level) were designed (Table 2). Figure 5 shows the topology of the neural network that has been used where the input and output parameters of the experiment are shown. In this study, we used the MATLAB R2013a software.

Table 2- Parameters affecting the level of the overall sound of the tractor engine.

Variable levels							Variables
E12D88	E10D90	E8D92	E6D94	E4D96	E2D98	E0D100	**Fuel blend**
2100	2000	1900		1800	1700		**Engine speed**



Figure(5) the used neural network topology.

To achieve good response, back propagation algorithm was used for training artificial neural network. Learning process by the above algorithm is an iterative process that involves changing the weights between different layers, which moves toward the stabilization of the weights in the training program, to minimize the error between the actual values and expectations. Given that one hidden layer is sufficient for solving function approximation problems (Fausett, 1993), in determining the best training algorithm, a hidden layer was used and the number of hidden layer neurons were obtained by trial and error. There are several training algorithms for propagation, among which the learning algorithmwith variable learning rate, Levenberg Marquardt, and gradient descent with momentum in estimating function problems that indicated better performance and presented and evaluated in this paper. For the purpose of training, the data were randomly divided into three parts in a way that 98 data for training, 21 data for testing the network and 21 data were used for network valuation. The average error rate for the training of multilayer perceptron networks with the back-propagation algorithm was tested with different topologies. Thus, the mentioned algorithm selected and optimized. After selecting the input and output data of the network, normalization, selecting training algorithms, actuator function, number of hidden layer neurons, number of hidden layers, number of repetitions (epoch), training parameter values and performance, training network using each of the algorithms, with a hidden layer and 5 neurons in the hidden layer, began, continued and increased to a maximum of 20 neurons. In this study, the performance function MSE was assigned 10^{-6}.

To find the best prediction, se eral neural networks were developed and trained with experimental data. To better evaluate the erformance and selecting the optimal network, regression analysis and correlation coefficient was exerted between the network output and the desired output (experimental data) and the error obtained in this step was calculated. Optimal number of hidden neurons in training algorithms was determined based on the highest correlation coefficient and the lowest error. With an optimal number of neurons in the hidden layer, using error and trial method, you can determine the type of stimulus function, training parameters values and the number of intermediate layers which by better performance, the network would be selected as the optimal network. However the best network was detected based on the highest correlation coefficient in training stage, testing and evaluation, and the lowest error. The creation and selection of appropriate model to predict the overall sound pressure level with A weight scale in the other pass-by people situation is given in Figure 6.

2. Analysis of results

One of the problems in the training of neural networks is over-fitting. The over fitting is that after training the network, the error on the training set reaches its minimum value, but with the introduction of new data on the network, as inputs, the error is high. To prevent over fitting error due to the method of auto-tuning, early stopping technique was used. In this method, the available data were dividen into three subsets, 70% of data as training subset, 15% of data as validation subset and 15% as a subset of the experimental data, showed better results in reducing the model error. The number of hidden layer neurons was varied from 5 to 15 neurons that the

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optimal number for each training algorithm and MSE error is presented in Table (3). Figure (7) is related to training network procedure using the Levenberg-Marquardt and trainlm code. As can be seen, the network MSE error gradually decreased, and after 13epochs, the network training will be stopped with the message "Validation Stop", which represents the increase in the validation set error. Weights and biases are adapted according to the time when the error has been minimal. Similarity between test set error and the validation set shows the desired model results. In order to get more accurate evaluation of the model, regression analysis between the network outputs and the desired targets were assessed. The correlation coefficient obtained in the prediction of the overall sound pressure level with A weight scale at the other pass-by people 0.97784 position (Figure 8). Also with reviewing the experimental and predicted data for designed neural network, the maximum error ±0.6 dB was determined for 94/6% of data. The results indicate the high accuracy of artificial neural network after propagation, with two neurons in the input layer and one neuron in the output layer, in predicting the sound pressure level of the weighted scale A in other pass-by people position.

Table 3- Characteristics of the networks created.

MSE	R	number of neurons in the hidden layer	Training algorithm
0.080776	0.82445	13	Traingdx
0.08754	0.9285	13	Traingda
0.027237	0.97784	15	Trainlm
0.083531	0.9388	14	Trainscg

3. Conclusion

Accurate evaluation of the total received sound is vital in selecting the engine speed variable values and various mixtures of fuels due to the unfavorable effects of engine noise on the health of the tractor driver and pass-by persons. Artificial neural networks were employed as a means to nonlinear mapping in this research as a novel approach that could intelligently discover the link between dependent and independent variables without resorting to mathematical modeling. The total volume of a tractor was predicted using the two variable factors of engine speed and fuel mixture. The results showed that the best correlation coefficient (R=0.97784) and the lowest square mean error value (0.0272) were achieved by a Multilayer Perceptron Network using a back-propagation learning algorithm and the Marquardt learning rule, with two neurons in the input layer and one neuron in the output layer.

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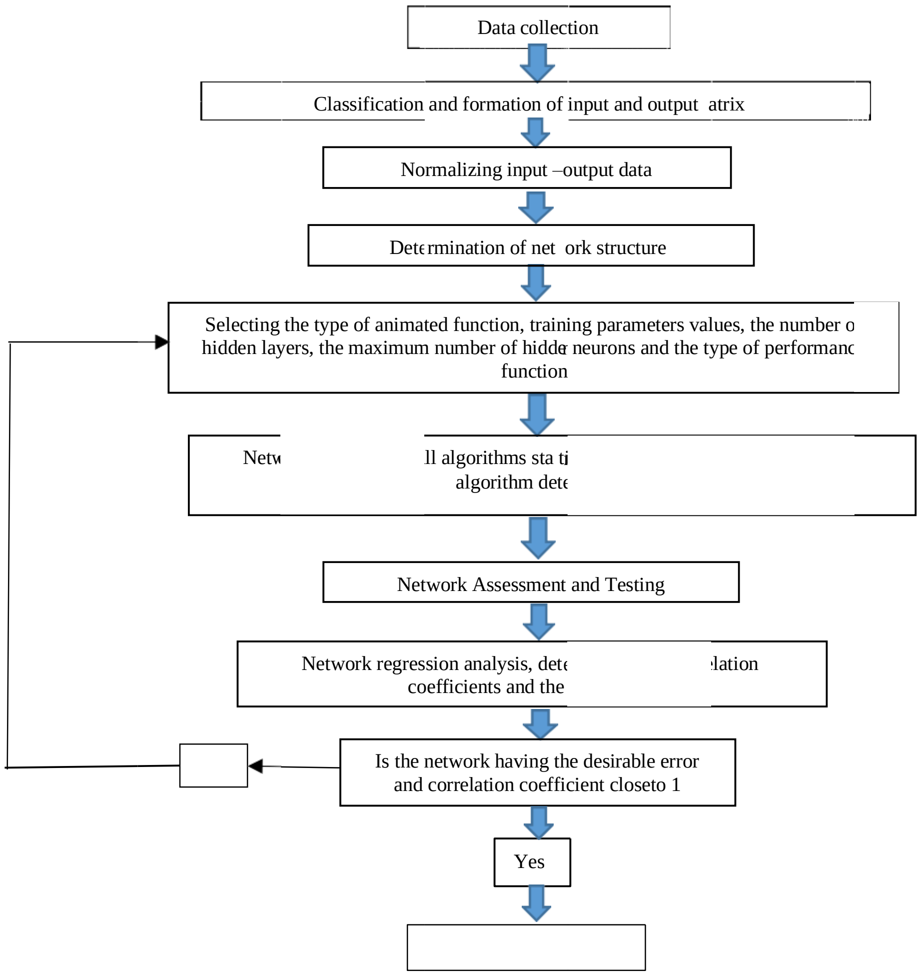
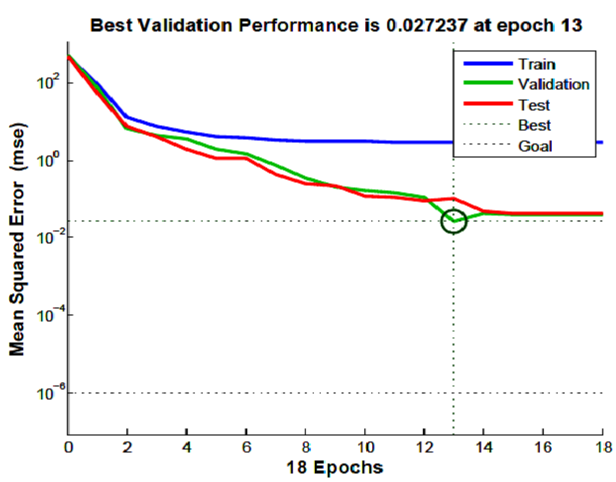


Figure (6) Steps to create and select the predicting overall sound pressure level model with A weight scale at other pass-by peopleposition.



Figure(7) variations in MSE error procedure using the Levenberg-Marquardt training network (Trainlm).

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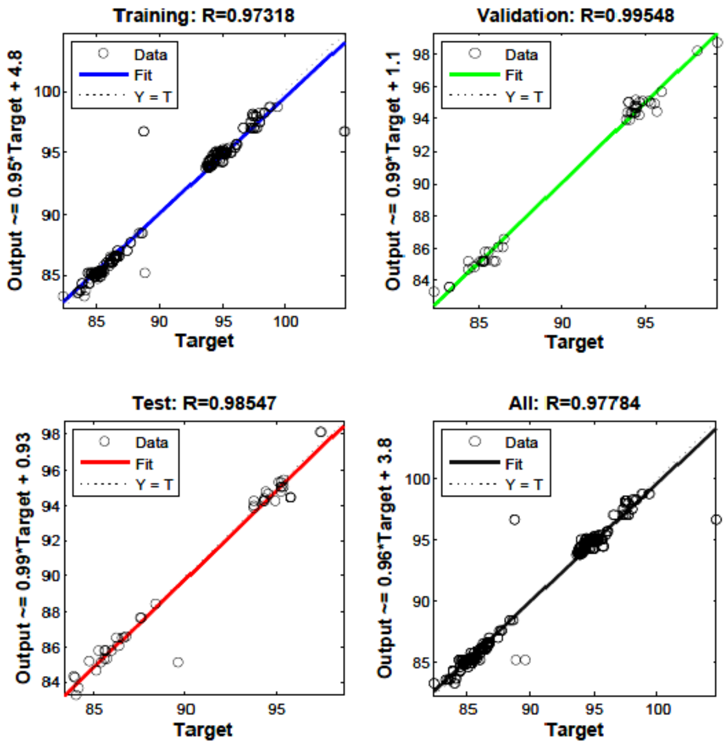

Figure(8) Regression analysisbetweenthe network outputandthe desired outputto predictthe overallsoundpressure levelwithA weightscaleinthe driversituation.

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