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ENVIRONMENTAL HAZARDS AND ECONOMIC LOSSES DUE TO SPEED REDUCTION ON DETERIORATED PAVEMENT

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ABSTRACT
Pavement condition has significant impact on average speed of vehicles. Pavement deterioration reduces average speed of vehicles which causes increase in fuel consumption which leads to environmental degradation and increases fuel cost. This research is based on the utilization of the concept of reduction of average Speed of vehicles and its effect on economic losses and environmental degradation due to extra fuel consumption. Two sections are considered, one for the base case scenario with good surface condition and second for the alternative case scenario with deteriorated surface condition and the Average Speed at those sections were determined for heterogeneous traffic. From the average speed of both scenarios VOC (vehicle operating cost) is calculated for the fuel consumption by Hepburn model and the CO (carbon monoxide) and NOx (nitrogen oxide) emissions were calculated for both scenario. The results revealed a strong impact of average speed of vehicles on emissions and travel cost..

Keywords:
Average Speed, VOC (vehicle operating cost), and Hepburn Model.

INTRODUCTION

Transportation infrastructure is key to developing economy of a country. A prolific and an efficient system is the need of the day. Transportation infrastructure mainly encompasses roads, railways airways and waterways. One the fundamental part of transportation is roads especially for third world countries Roads provide the essential links, facilitates the movements of subjects and goods. Increase in traffic volume, poor quality, ill maintenance and unskilled construction practices and lack of coherence in understanding and implementation causes the pavement surfaces deteriorates which reduces the average speed of vehicles. The reduction in average speed leads to high fuel consumption which causes economic losses in terms of VOC (vehicle operating cost) and causes environmental degradation due to high emissions of carbon monoxide (CO) and Nitrogen Oxide (NOx).

BTS (1997) and Homburger et al. (2001) states that from 1960 to 1970 air pollution increased severely but decreased afterwards even though number of vehicles increased drastically. One of the main reasons of reduction of pollutant emissions is the strict government policy through the establishment of increasingly restrictive federal emission standards. The allowable level of carbon mono oxide emission from a car was reduced to 3.4 g/mi from a level of 7 g/mi during 1980 to 1985. The actual reductions may or may not be smaller because the standard tests do not portray real driving conditions; and harmful emissions from vehicles are typically not measured in these tests

USEPA (2005) Report include that In last 10 years, 45% of the volatile organic compounds (VOCs), the 83% of the carbon monoxide (CO), and 53% of the nitrogen oxide (NOx) emissions in the United States is contributed by transportation system.

Chatterjee et al 1997) Research shows that the major factors that affect the level of vehicle emissions can generally be categorized as follows: driver-related, highway-related, fuel type, vehicle-related, travel related, and environmental. Information on the sensitivity of vehicle emissions in response to changes in these factors is provided by NCHRP study (Report 394).

EPA Report says that the speed, type, and acceleration of a vehicle and the load on its engine have a very huge impact on the level of emissions. At low speeds HC and CO are highest. The report says that for most types of vehicle, CO and NOx emissions generally are higher at lower speeds, decreases with increase in speed to their

minimum rates, and then stay flat or increase slightly depending on the vehicle or fuel type, or the pollutant in question. The smoothness and consistency of vehicle speed, traffic conditions, and driving behavior can influence emissions. Sharp acceleration at a high speed and heavy load on an engine require more fuel to feed the engine, thus generating more HC and CO emissions but cause little change in NOx emissions. Rakha et al (1999) Says that certain facility designs can encourage transportation vehicles to operate at low emitting speeds or modes. For highway transportation, examples include low grade, existence of ramps and signals, acceleration and deceleration lanes, and channelization. It has been shown, for example, that traffic signal coordination can result in up to a 50% reduction in emissions under certain circumstances. Bennett et al (1991) Vehicle operating speed is the dominant factor in determining VOC.

MATERIALS AND METHODS

The Study Areas

This study was conducted in district Charsadda region Khyber Pukhtunkhwa, Pakistan on an arterial road.

AVERAGE SPEED

Two section excellent and failed surface conditions were identified on the basis of PCI and average speed for heterogeneous speed was calculated at those sections. For average speed calculation two cameras were installed at starting (0+000 m) and end point (0+050 m) of the study section. The elapse time for each passing vehicle is calculated from that videos and an average of each type of vehicle was calculated.

Figure 1.1 (a) shows good condition while (b) shows failed condition scenario

The average speed was calculated for light vehicles and heavy vehicle at sections with good and failed surface condition.

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Figure 1.2 Camera and Video recording setup for average speed calculation

VEHICLE OPERATING COST BY HEPBURN MODEL

Hepburn (1994) developed a VOC model for urban roadways that considers the sum of four VOC components (tires, vehicle depreciation, maintenance, and fuel) as a function of two VOC factors: speed and vehicle class. The model is particularly useful for evaluating VOC impacts of transportation interventions that mostly yield a change in average operating speeds or policies that cause a shift in vehicle class distribution. The Hepburn function is as follows:

For "low" average travel having Speed less than 50 km/hr.

$VOC = C + D/S$

For "high" average speed having speed higher than 50kmlhr

$VOC = a_0 - a_1 * S + a_2 * S^2$

As "S" is the average speed of the vehicle the rest of the values are given according to Hepburn model.

Table: Hepburn model Data

Vehicle type	C	D	a0	a1	a2
small vehicle	24.8	45.5	27.2	0.035	0.00021
Large vehicle	29.8	163.4	38.1	0.093	0.00033

CALCULATION OF VEHICLE EMISSIONS

The variation carbon monoxide (CO) and nitrogen oxide (NOx) due to change in average speed is calculated according to (Faiz et al 1996) research.

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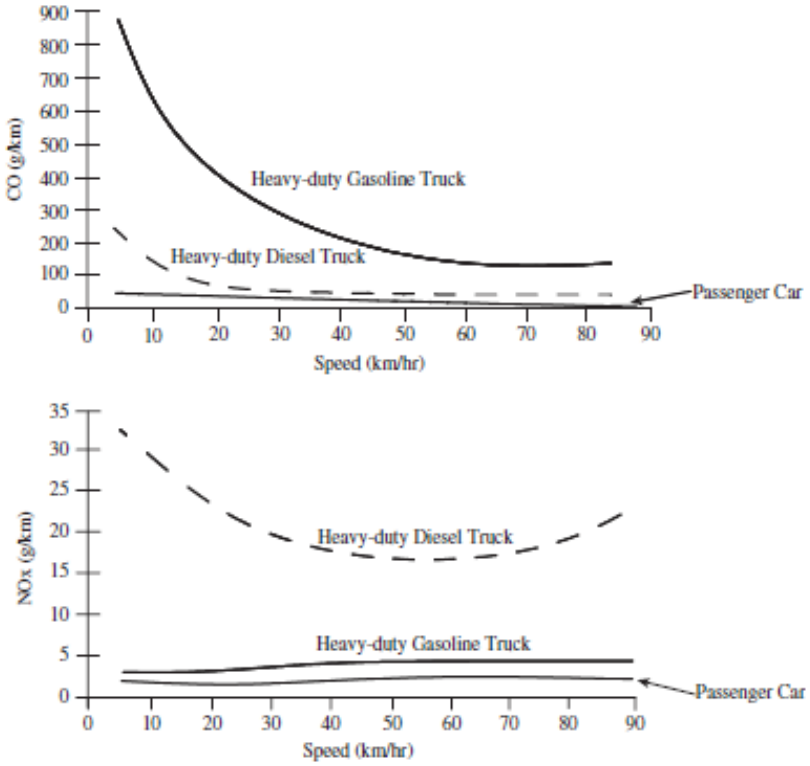

Figure 1.3 Variation in CO and NOx due to speed (by faiz et

RESULTS AND DISCUSSION

AVERAGE SPEED

The average speed is calculated on both section by categorizing the vehicles in light weight and heavy weight vehicles. The average speed for both type of vehicle is given in the table below.

Table: Average speed of Vehicles

Average speed (miles/hr.)		
Vehicle Type	Best	Failed
Light Vehicle	55.38	11.9
Heavy vehicle	50.075	10.475

The speed shows significant reduction in deteriorated pavement section. The Annual average daily traffic (AADT) and vehicle mile travel (VMT) are calculated on that road.

Table: AADT and VMT data

Link	Length (Miles)	AADT		VMT	
		Light Vehicle	Heavy Vehicle	Light Vehicle	Heavy Vehicle
Best	2	4406	875	8812	1750
Failed	2	4406	875	8812	1750

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VEHICLE EMISSION

Carbon monoxide and nitrogen oxide emitted by vehicles to the environment are calculated are given in the table below

Table: CO and NOx emitted

Avg Speed (mph)		Daily Emissions CO (Tons)		Total (Tons)	Daily Emissions NOx (Tons)		Total (Tons)
Light Vehicle	Heavy Vehicle	Light Vehicle	Heavy Vehicle		Light Vehicle	Heavy Vehicle	
55.38	50.07	0.70	0.25	0.95	0.05	0.09	0.14
11.9	10.47	0.97	0.61	1.58	0.05	0.11	0.15

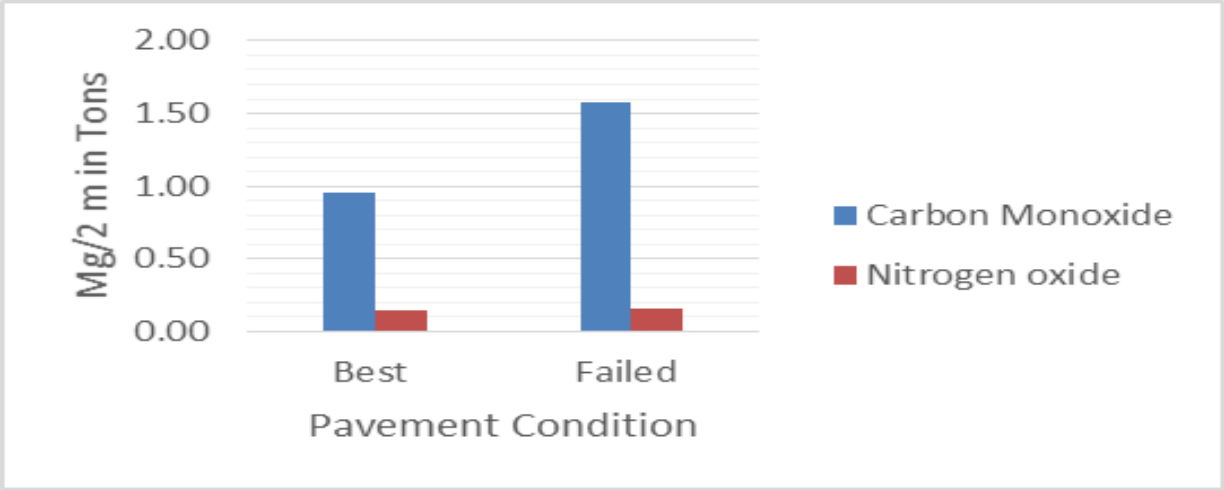

Figure: Carbon Monoxide (CO) and NOx Emissions

The total CO emission increases from 0.95 ton to 1.58 Ton while nitrogen oxide increases from 0.14 to 0.15 ton/day per 2 Km of length. The increase in CO is relatively higher than NOx due to reduction in traffic speed.

I. Vehicle operating cost

The vehicle operating cost is calculated by Hepburn model. As the reduction in average speed increases vehicle operating cost due to higher fuel consumption a model developed by Hepburn is used to calculate that increase in VOC. The VOC data is given in the table below

Table: Vehicle operating cost on the basis of Average speed calculated by Hepburn model

		Good	Failed
Average Speed (MPH)	Light Vehicle	55.38	11.90
	Heavy Vehicle	50.08	10.48
VOC Cents /Vehicle/Km	Light Vehicle	25.62	26.81
	Heavy Vehicle	33.06	37.16
VOC/VMT	Light Vehicle	225777.51	236278.25
	Heavy Vehicle	57860.43	65033.56
Amount	Total	283637.94	301311.81
	Total Amount In Dollars	2836.38	3013.12

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The average speed at the failed section shows 78.5% reduction for light vehicles and 79% for the heavy vehicles at failed section as compare to the best section. As the VOC depends on the Average speed therefore there is economic losses due to pavement condition. The VOC increases up to 6% as compare to the best condition.

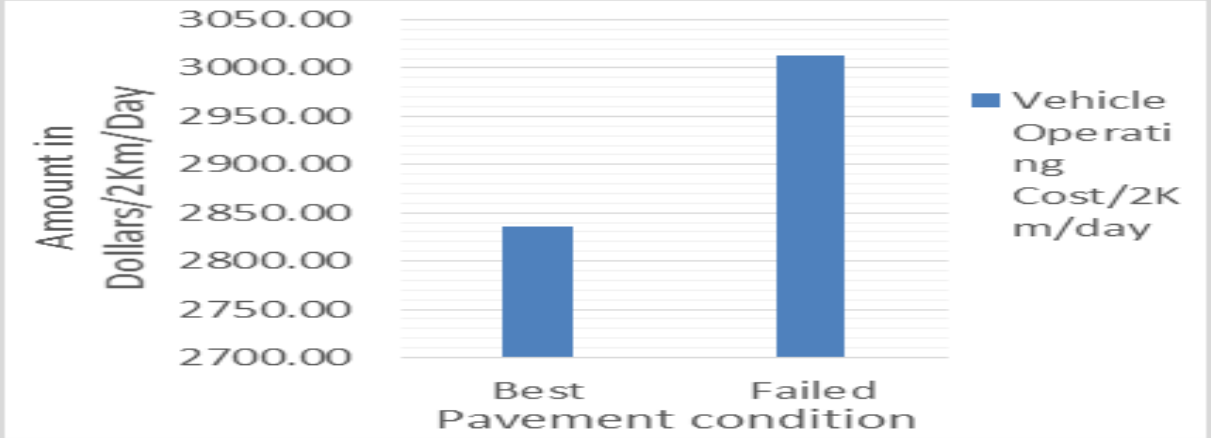

Figure: Vehicle operating Cost at Different pavement Condition

CONCLUSIONS AND RECOMMENDATIONS

The average speed of vehicles reduces up to 78.5% and 79 % for both light and heavy vehicles consecutively. The increase in Carbon monoxide emission at failed section increases from 0.95 ton to 1.58 ton shows an increase of to 40%.The Nitrogen Oxide emissions increases from 0.14ton to 0.15ton shows an increase of 10% at failed section. The total emissions increases 37% at failed section. The vehicle operating cost increase from 2836 dollars 3013 dollars for a stretch of 2 miles per day which is an increase of 6%.

As the pavement Condition Effects average speed which has some serious consequences on the environment therefore, the road must be maintenance on time. The Economic losses due to increase in VOC by average speed is need to be consider during planning of a road. The effect of surface deterioration on social behavior is need to be identified in future work.

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