An Optimum Fuel Consumption Model for the Transport of Cargoes by Road Vehicles

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Introduction:

Energy Consumption in Transportation

- 40% of Total Energy, 23% Direct, 17% Indirect
- 40% of Total Fossil Fuels
- Road Transportation is the Largest Fuel Consumer
- 25 Trillion Liters of Consumed Fuel in 2001 in Iran
- Figures 1,2,3

Figure 1: Energy Consumption in Major Sectors

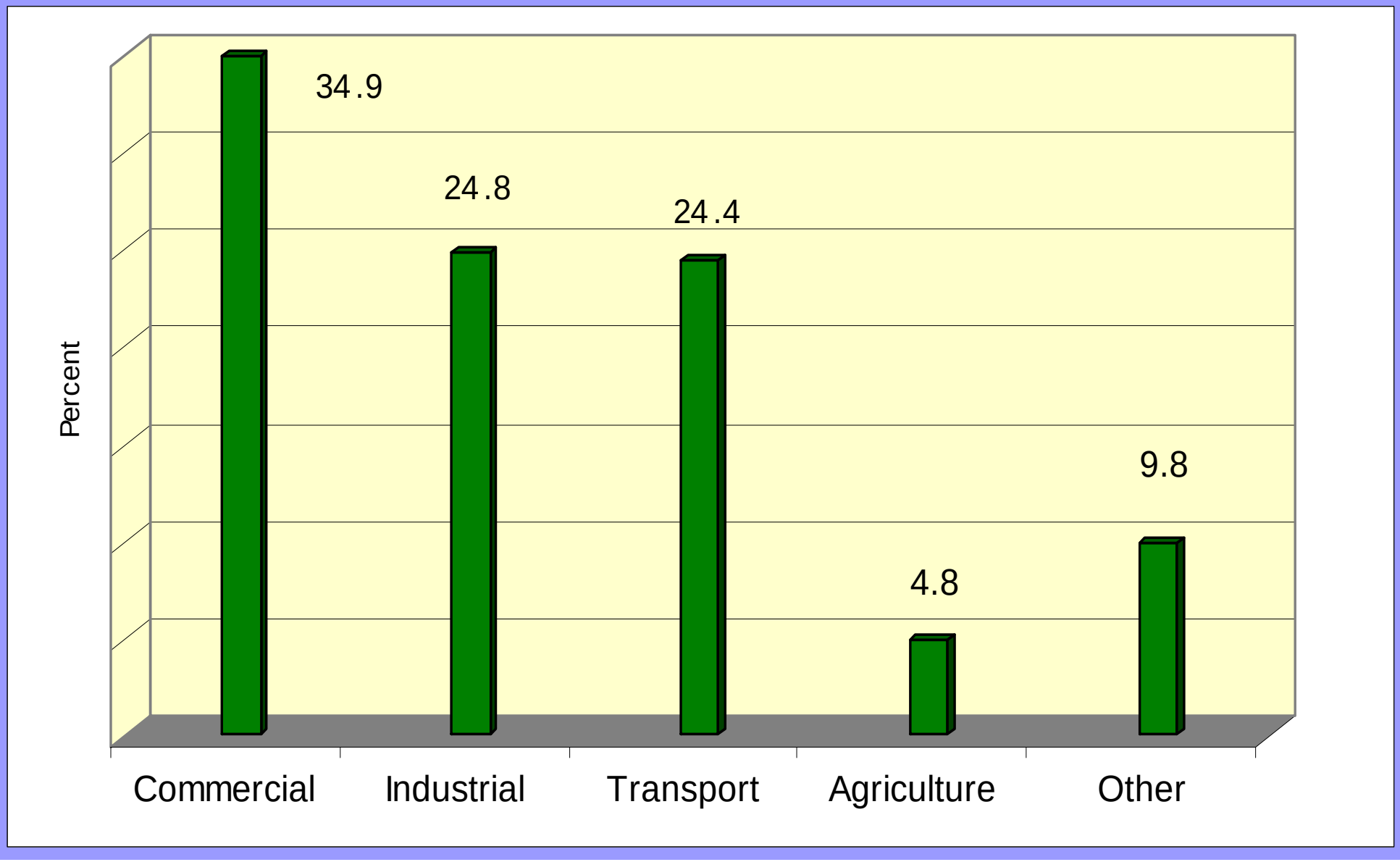


Figure 2: Energy Consumption in Transportation (Million barrel)

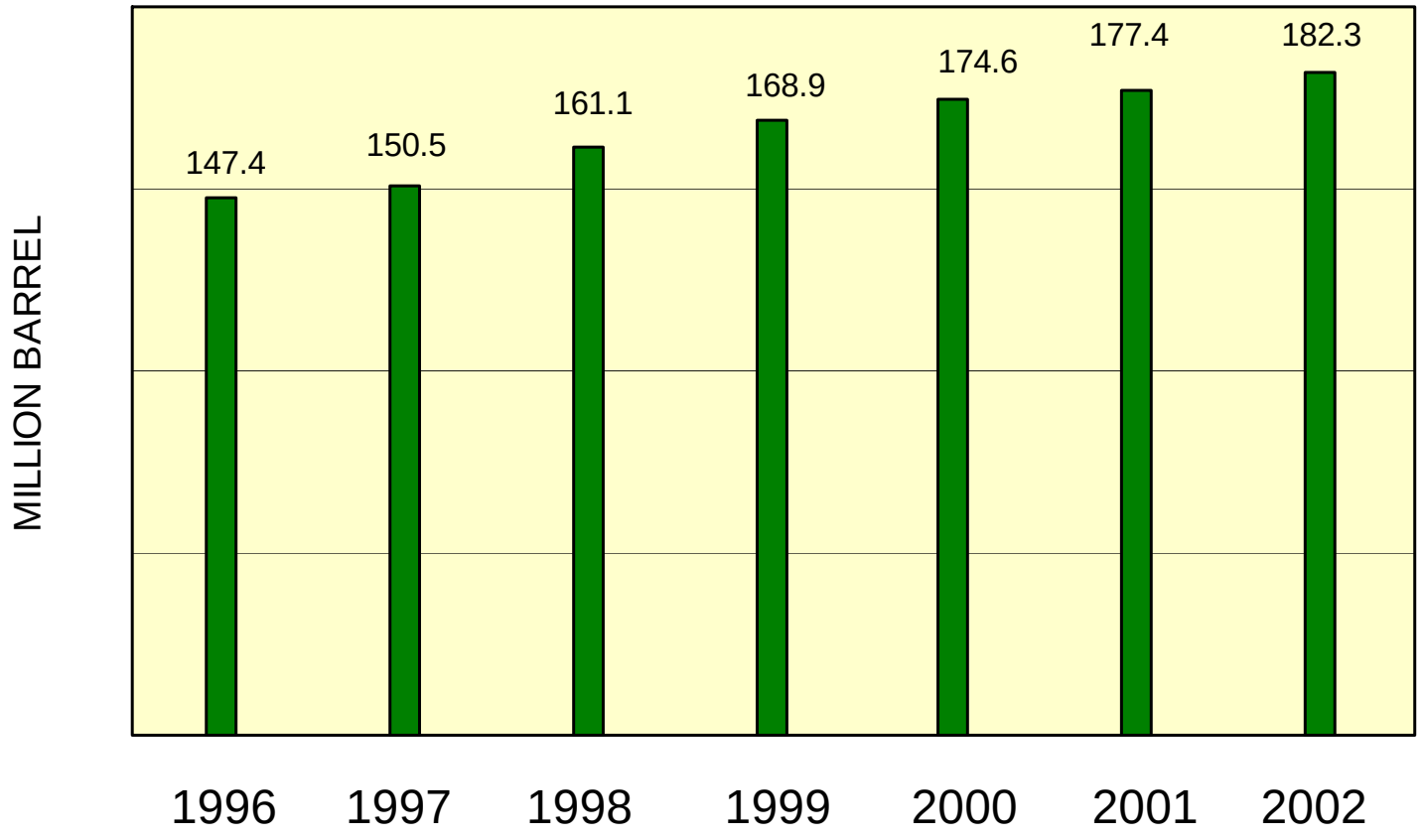
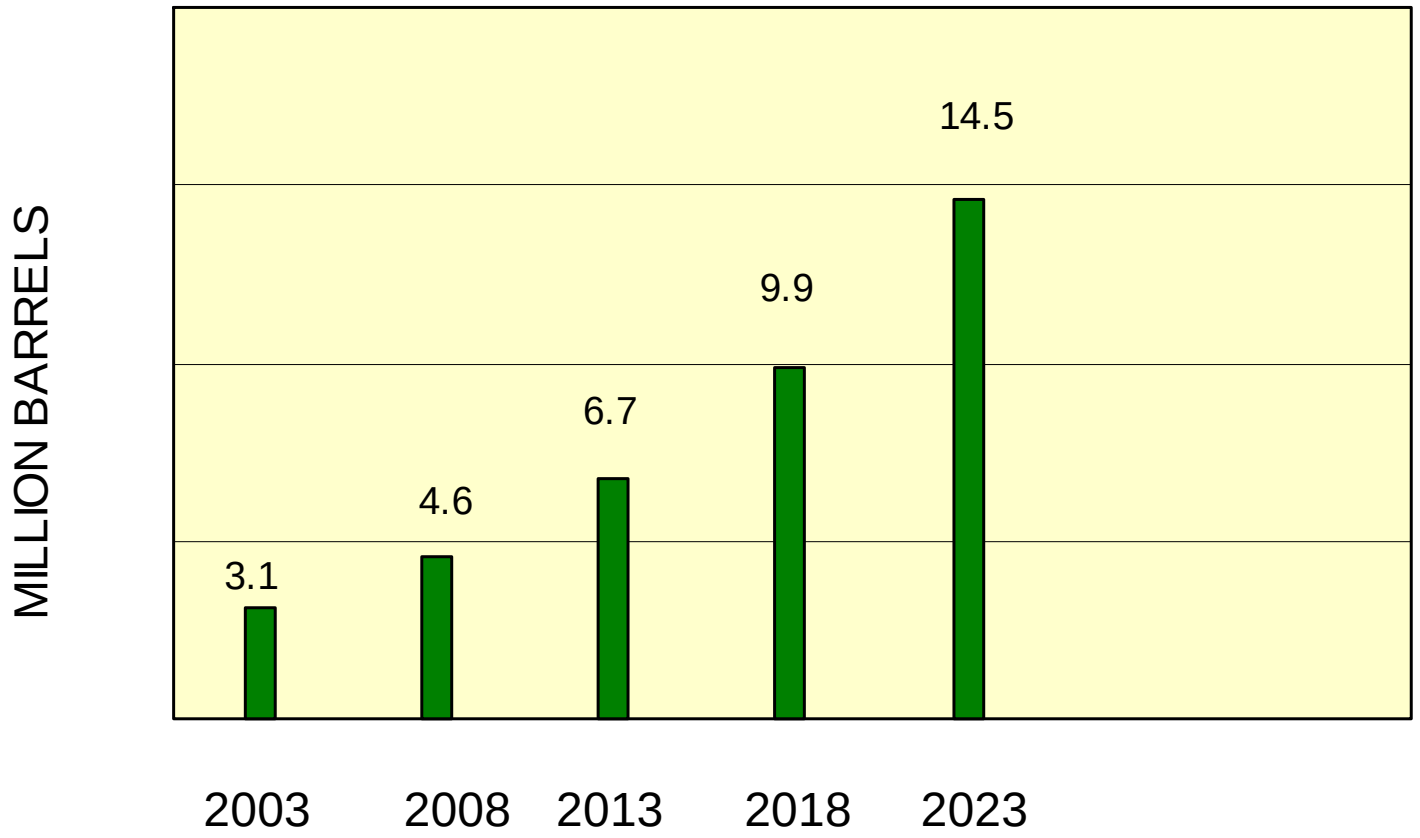


Figure 3: Forecast of Fossil Fuel Consumption In Iran



Factors Affecting Fuel Consumption in Road Transportation

- Geometric Design of Highways (Slope, Alignment, Surface,...)
- Traffic Flow Characteristics (Volume, Density)
- Vehicle Characteristics (Speed, Weight, Type,..)
- Fuel Type (Diesel, Gasoline, CNG,..)
- Driver Behavior (Acceleration, Deceleration, Education)
- Environmental Parameters (Rain, Temperature, Snow...)

Literature Review:
a) Drivers' Behavior Models:

$$G = f_1 L + f_2 D + f_3 S$$

G = Consumed fuel for each car during the traveled distance

L = Whole traveled distance

D = Static delay for each car

S = Number of stops

f_1 = Rate of fuel consumption in distance unit during action (travel)

f_2 = Rate of fuel consumption in time unit during static case

f_3 = Utilized extra fuel for decreasing the speed to stop or increasing speed to reach travel speed.

b) Gary Hicks and Clarkson Model

$$Q_m = 16.57 \times P_m \times V^{-1} \times \exp(0.0195V)$$

Q_m = the average fuel consumption rate of the vehicle type m on the basis of liter per 100km.

P_m = the average fuel consumption rate of vehicle type m, with the speed of 30 km/hr.

V= the average speed of the vehicle

Research Methodology

- List of Parameters in the Vehicle Speed
- Selection of Effective Variables
- Analysis of Collected Data from 41 Roads
- Development of Alternative Speed Models
- Selection of Optimum Fuel Consumption Model

Table 1: Variables Used in Estimation of Models

No	Variable	Function Type Used in the Model	Unit
1	Average slope	TOPO	-
2	Width of the road	W	Meter
3	Sight distance	SIGHT-DIS	-
4	Shoulder	ADGE	Meter
5	Right of Way	WAYSIGHT	Meter
6	Topography of the Road	M=Mountain L= Land T=Terrain	-
7	Total Passenger Car Equivalent	PCE TOTAL	PCE
8	Passenger Car Equivalent for Trucks	PCE TRUCK	PCE
9	Ratio of Truck PCE to Total PCE	$\frac{\text{PCE TRUCK}}{\text{PCE TOTAL}}$	-
10	Level of Service	L.O.S.	-

Figure 4: Function of Speed-Fuel Consumption

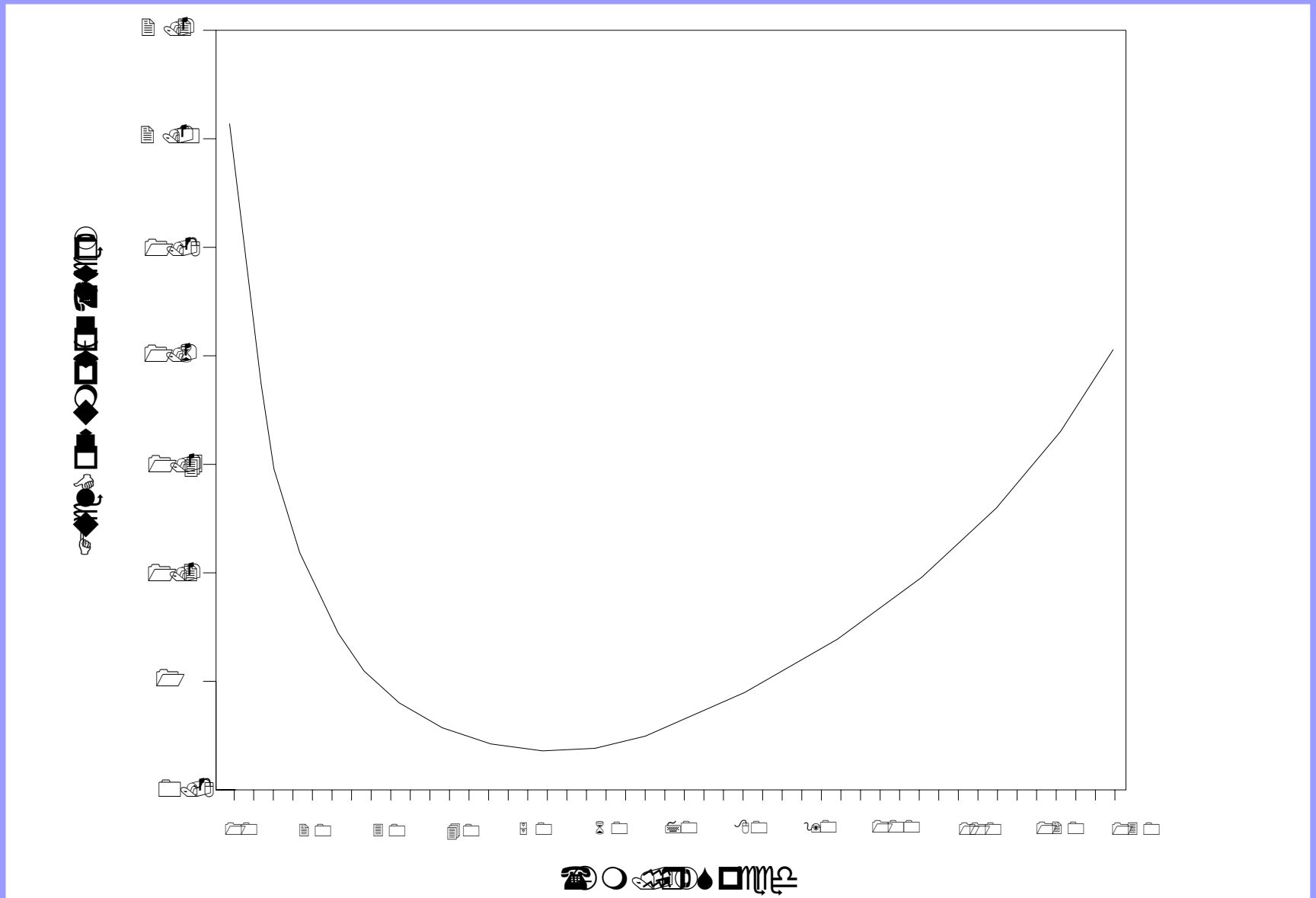


Table 2: Comparison Between Linear and Logarithmic Functions

Linear function		Logarithmic function	
Variables	**Selected Model**	**Variables**	**Selected Model**
Fixed	64.96 (8.489)	Ln(Fixed)	57.672 (16.101)
ADGE	4.327 (1.816)	Ln(ADGE)	8.638 (1.956)
TOPO	-3.377 (-9.237)	Ln(TOPO)	-11.729 (-8.635)
L.O.S.	-15.77 (-3.421)	Ln(L.O.S.)	-1.918 (-2.432)
$\frac{\text{PCE TRUCK}}{\text{PCE TOTAL}}$	-5.94 (-1.048)	$\text{Ln}[(\frac{PCE\ TRUCK}{PCE\ TOTAL})]$	-3.95 (-0.948)
R^2	0.8	R^2	0.79
SE	2.83	SE	2.87
F	36.92	F	35.25
N	41	N	41

Alternative Models

a) Linear

$$V = 65 + 4.3(ADGE) - 3.4(TOPO) - 15.8(L.O.S.) - 5.9\left(\frac{PCE\,TRUCK}{PCE\,TOTAL}\right)$$

b) Logarithmic

$$V = 57.7 + 8.6(ADGE) - 11.7(TOPO) - 1.9(L.O.S.) - 3.9\left(\frac{PCE\,TRUCK}{PCE\,TOTAL}\right)$$

c) Optimum Model

For Speed:

V=65+4.3(ADGE)-3.4(TOPO)-15.8(L.O.S.)-5.9

d) For Fuel Consumption

$$Q = 62.8 \times \frac{EXP[[65 + 4.3(ADGE) - 3.4(TOPO) - 15.8(L.O.S.) - 5.9(\frac{PCE\ TRUCK}{PCE\ TOTAL})]0.0195]}{[65 + 4.3(ADGE) - 3.4(TOPO) - 15.8(L.O.S.) - 5/9(\frac{PCE\ TRUCK}{PCE\ TOTAL})]}$$

Conclusions and Recommendations

- Heavy Vehicles Fuel Consumption Depends on Many Variables From Which Some Important Ones Have Been Selected.
- Summary of Results, Table 3-1, 3-2

Table 3-1: The Impact of Model Variables on the Fuel Consumption

Variable	Increase of the Variable for Optimizing the Fuel Consumption			Increase of the Speed (Km/hr)
AGDE	0.5m Shoulder Increase	0.20	0.002	2.16
TOPO	1% Decrease of the Slope	0.487	0.00487	3.337
L.O.S.	0.1 Increase in L.O.S.	0.0119	0.000119	-1.577
$\frac{TRUCK}{TOTAL}$	1% Decrease of Trucks Ratio to Total	0.01	0.0001	0.06

Table 3-2: The Impact of Model Variables on the Fuel Consumption

Variable	Decrease of the Variable to Increase the fuel Consumption			Decrease of the Speed (Km/hr)
AGDE	0.5m Shoulder Increase	0.20	0.002	2.16
	No Shoulder	1.037	0.01037	10.82
TOPO	1% Slopes as Compared to 0	0.487	0.00487	3.377
L.O.S.	0.1 Decrease in L.O.S.	-0.0341	-0.000341	-1.577
$\frac{PCE\ TRUCK}{PCE\ TOTAL}$	1% Increase of Trucks Ratio to Total	0.01	0.0001	0.06

- **Finally Combination of Fuel Consumption Model and Traffic Management Models Can be Used For Transportation Network Planning, Regarding the Cost and Frugality In Fuel Consumption.**

Thank you for your Patience