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On Optimizing Mileage and Amount of Air Pollutants From Automobiles: A Goal Programming Approach

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ABSTRACT

Automobile industry is fast growing industry in developing nations. The number of vehicles has increased manifolds during the last few decades in our country. As a result of this increase the consumption of fuel and production of air pollutants has also been increased up to a large extent.
As we all know that we are going to face a serious crisis of automobile fuels in near future so it becomes necessary that our vehicles must consume less fuel and there must be an increase in annual mileage of vehicles. But on the contrary it is also necessary that amount of air pollutants released by each vehicle must be reduced in order to tame the problem of air pollution and related diseases. Environmental pollution is a matter of serious concern in this era. Almost every person on this planet is a victim of this poison and our basic sustainable resources are being poisoned due to various pollutants coming out of our vehicles. The irrational use of vehicles is increasing amount of pollutants geometrically.
In this paper we are trying to propose a Lexicographic Goal Programming (LGP) model to optimize the amount of pollutants coming out of different vehicles and their annual mileage in order to control amount of air pollutants in our space.

KEYWORDS Annual mileage, air pollutants, optimizing, Lexicographic Goal Programming

INTRODUCTION

In today's fast life the use of automobiles is an inseparable part of our life style. It is a necessity and not a luxury now. Besides making our journey easy and time saving it is a large employment providing and revenue producing sector. We cannot think of life without automobiles in today's world. Besides making our life easier automobiles are mixing poison to the air we breathe and a huge amount of fossil fuel is being burnt. To meet the increasing demands of petroleum products drilling is being done at a large scale which is disturbing ocean ecosystems.

In today's world we cannot even imagine to abort the use of automobiles because it will stop the life line of whole economy. Thousands of people will become unemployed and whole economy will come to an end. Apart from this it is the high time to be concerned about our ecosystem otherwise the date of extinction of Homo sapiens from this planet is very near.

The automobiles running on our roads are consuming hydrocarbons and producing huge amount of pollutants like carbon monoxide (CO), unburnt hydrocarbons (HC), oxides of nitrogen (NO_x), and carbon dioxide (CO_2). The uncontrolled emission of these hydrocarbons in ambient air is really harmful to life as well as property as these affect them adversely.

In urban areas – both developing and developed countries, it is predominantly mobile or vehicular pollution that contributes to overall air quality problem. In Delhi, the data shows that of the total 3,000 metric tonnes of pollutants belched out every day, close to two-third (66%) is from vehicles. Similarly, the contribution of vehicles to urban air pollution is 52% in Bombay and close to one-third in Calcutta. Katz (1994) has estimated that in Santiago, Chile, wherever pollution concentration exceeds ambient standards, mobile sources or vehicles are the cause. Similarly, in case of Budapest, Hungary, transport is the dominant source of emissions except sulphur dioxide (SO_2), contributing 57% of Oxides of Nitrogen (NOx), 80% of lead (Pb), 81% of carbon monoxide (CO) and 75% of hydrocarbon (HC) emissions (Lehoczki, 2000).

A number of countries have targeted vehicles and associated sectors to curb the menace. Notable successful initiatives are: conversion of public transport from diesel to CNG in Delhi, switching of Vikrams (tuk-tuks) from diesel to electricity in Kathmandu valley, shifting from leaded to unleaded gasoline in many countries etc. Still the pollution problem in urban cities may continue to loom large due to ever-burgeoning vehicular population, which is outpacing any such measure and road network development. Following data gives a glimpse of such skewed growth. Against 1.9 million vehicular populations in 1990 in Delhi, it rose to nearly 3.6 million in the year 2001 (i.e., an increase of nearly 87%). During the same period, Delhi's population has increased by only 43% (from 9.5 million to 13.8 million) and road-length by merely 14% (from 22,000 Km to 25,000 Km) respectively. Situation is similar across a number of cities in India and the developing world. This indicates the exigency of controlling vehicular pollution.

The worst thing about vehicular pollution is that it cannot be avoided as the emissions are emitted at the near-ground level where we breathe. Pollution from vehicles gets reflected in increased mortality and morbidity and is revealed through symptoms like cough, headache, nausea, irritation of eyes, various bronchial problems and visibility. The pollution from vehicles are due to discharges like CO, unburned HC, Pb compounds, NOx, soot, suspended particulate matter (SPM) and aldehydes, among others, mainly from the tail pipes. A recent study reports that in Delhi one out of every 10 school children suffers from asthma that is worsening due to vehicular pollution. Similarly, two of the three most important health related problems in Bangkok are caused by air pollution and lead contamination, both of which are contributed greatly by motor vehicles.

The different air pollutants due to vehicles can have effects at all the three levels – local (e.g., smoke affecting visibility, ambient air, noise etc.), regional (such as smog, acidification) and global (i.e., global warming). The vehicles besides being the prominent source of air pollutants also account for a number of external effects, such as congestion, noise, accidents, road wear and tear, and 'barrier effects'.

The details of these pollutants are as:

Carbon Monoxide (CO): It is a product of the incomplete burning of fuel and is formed when Carbon is partially oxidized. CO is an odorless, colorless gas, but is toxic in nature. It reaches the blood stream to form Carboxy-haemoglobin, which reduces the flow of Oxygen in blood.

Oxides of Nitrogen (NOx): Combustion under high temperature and pressure emits Nitrogen dioxide. It is reddish brown gas. Nitrogen oxides contribute to the formation of ground level Ozone and acid rain.

Hydrocarbons (HC): Hydrocarbons result from the incomplete combustion of fuels. Their subsequent reaction with the sunlight causes smog and ground level Ozone formation.

Carbon dioxide (CO_2): CO_2 is a quantitative pollutant i.e. it is a pollutant only if its quantity exceeds a certain limit otherwise its presence is necessary in some amount in our atmosphere. It is produced due to burning of hydrocarbons in presence of oxygen.

GOAL PROGRAMMING:

Goal programming (GP) was firstly introduced by Charnes and Cooper in the year 1961 and was further developed by Ignizio, Lee, Romero, etc. It is the technique of optimization of a number of goals and their multiple sub goals simultaneously.

GP is a fancy name for a very simple idea: the line between objectives and constraints is not completely solid. In particular, when there are a number of objectives, it is normally a good idea to treat some or all of them as constraints instead of objectives.

GP is a modification and extension of linear programming. The goal programming approach allows a simultaneous solution of a system of complex objectives other than a single objective i.e. it a technique which is capable of handling decision problems that deal with a single goal and multiple sub-goal, as well as problems with multiple-goals and multiple sub-goals. In addition, the objective functions of a goal programming model may be composed of non-homogeneous units of measure. GP approach is based on the concept of optimization of several conflicting goals precisely defined by the decision maker by minimizing the deviations from the target values. The original objectives are expressed as linear equations with target values and two auxiliary variables which represent the slack and surplus or the under- achievement and over- achievement respectively. The unwanted deviations between target values of objectives are minimized according to the priority.

Here we will try to prove the importance of LGP as an aid to optimize the average annual mileage and emissions of different vehicles with multiple objectives. This technique allows us to find us optimal solution based on priorities of goals in decision making environment. We have used LGP to study a set of goals and objectives as they relate to environmental significance of air conservation. The model uses Euclidean distance method to measure distances of all feasible solutions from ideal solutions. The optimal solution is determined based on minimum distances between ideal solutions and other possible solutions of the problem.

PRIORITY STRUCTURE:

1. Mileage Efficiency:

Goal 1: Maximize the mileage of vehicles running on road.

2. CO_2 Reduction:

Goal 2: Minimize the amount of CO_2 in vehicular emissions.

3 CO Reduction:

Goal 3: Minimize the amount of CO in vehicular emissions.

4 HC Reduction:

Goal 4: Minimize the amount of HC in vehicular emissions.

5 NO_x Reduction:

Goal 5: Minimize the amount of NO_x in vehicular emissions.

VARIABLES AND PARAMETERS:

The different variables and parameters which are used in the Equations are described as:

M_i = Annual mileage of the i^{th} type of vehicle.
E_{ij} = Amount of j^{th} type of pollutant emitting from i^{th} type of vehicle.
TE_j = Total emission amount of j^{th} type of pollutant.

CONSTRAINTS:

To formulate LGP model, the following goal constraints appear in the model:

Total emission of a certain type of pollutant can be expressed as:

$$\sum M_i \times E_{ij} + d_i^- - d_i^+ = TE_j$$ ……………………………[1]

Vehicle Type	Annual Mileage (km/yr)	CO_2		CO		HC		NO_x	
		g/km	Kg/yr	g/km	Kg/yr	g/km	Kg/yr	g/km	Kg/yr
2 Wheeler (4S)	10,000	26.6	266	2.4	24	0.7	7	0.3	3.0
3 Wheeler	40,000	115	4600	2.45	98	0.75	30	0.12	4.8
Passenger car	15,000	223.6	3354	1.0	15	0.126	1.89	0.127	1.905
Taxis	30,000	208.3	6249	1.0	30	0.126	3.78	0.127	3.81
Multi Utility Vehicle	37,000	515.2	19062.4	0.50	18.5	0.056	2.072	0.5	18.5
Light Commercial Vehicle	40,000	515.2	20608	0.50	20	0.030	1.2	0.025	1
Trucks	30,000	515.2	15456	1.4	42	0.39	11.7	2.45	73.5
Buses	60,000	515.2	30912	1.4	84	0.39	23.4	4.9	294
TOTAL	2,62,000		1,00,507.4		331.5		81.042		400.515

Table1: Annual mileage and amount of various pollutants from different categories of vehicles

For the data given in the table above GP problem is formulated as:

Mileage Efficiency Goal:

$$10{,}000X_1 + 40{,}000X_2 + 15{,}000X_3 + 30{,}000X_4 + 37{,}000X_5 + 40{,}000X_6 + 30{,}000X_7 + 60{,}000X_8 + d_1^- - d_1^+ = 2{,}62{,}000$$ ……………………[2]

Subject to constraints,

$X_1 + d_2^- - d_2^+ = 10{,}000$ ……… [3]
$X_2 + d_3^- - d_3^+ = 40{,}000$ ……… [4]
$X_3 + d_4^- - d_4^+ = 15{,}000$ ……… [5]
$X_4 + d_5^- - d_5^+ = 30{,}000$ ……… [6]
$X_5 + d_6^- - d_6^+ = 37{,}000$ ……… [7]
$X_6 + d_7^- - d_7^+ = 40{,}000$ ……… [8]
$X_7 + d_8^- - d_8^+ = 30{,}000$ ……… [9]
$X_8 + d_9^- - d_9^+ = 60{,}000$ ……… [10]

CO_2 Reduction Goal:

$$266X_1 + 4{,}600X_2 + 3{,}354X_3 + 6{,}249X_4 + 19{,}062.4X_5 + 20{,}608X_6 + 15{,}456X_7 + 30{,}912X_8 + d^- - d^+ = 1{,}00{,}507.4 \quad [11]$$

Subject to constraints

$$X_1 + d^- - d^+ = 266 \quad [12]$$
$$X_2 + d^- - d^+ = 4{,}600 \quad [13]$$
$$X_3 + d^- - d^+ = 3{,}354 \quad [14]$$
$$X_4 + d^- - d^+ = 6{,}249 \quad [15]$$
$$X_5 + d^- - d^+ = 19{,}062.4 \quad [16]$$
$$X_6 + d^- - d^+ = 20{,}608 \quad [17]$$
$$X_7 + d^- - d^+ = 15{,}456 \quad [18]$$
$$X_8 + d^- - d^+ = 30{,}912 \quad [19]$$

CO Reduction Goal:

$$24X_1 + 98X_2 + 15X_3 + 30X_4 + 18.5X_5 + 20X_6 + 42X_7 + 84X_8 + d^- - d^+ = 1{,}00{,}507.4 \quad [20]$$

Subject to constraints

$$X_1 + d^- - d^+ = 24 \quad [21]$$
$$X_2 + d^- - d^+ = 98 \quad [22]$$
$$X_3 + d^- - d^+ = 15 \quad [23]$$
$$X_4 + d^- - d^+ = 30 \quad [24]$$
$$X_5 + d^- - d^+ = 18.5 \quad [25]$$
$$X_6 + d^- - d^+ = 20 \quad [26]$$
$$X_7 + d^- - d^+ = 42 \quad [27]$$
$$X_8 + d^- - d^+ = 84 \quad [28]$$

HC Reduction Goal:

$$7X_1 + 30X_2 + 1.89X_3 + 3.78X_4 + 2.072X_5 + 1.2X_6 + 11.7X_7 + 23.4X_8 + d^- - d^+ = 81.042 \quad [29]$$

Subject to constraints

$$X_1 + d^- - d^+ = 7.0 \quad [30]$$
$$X_2 + d^- - d^+ = 30 \quad [31]$$
$$X_3 + d^- - d^+ = 1.89 \quad [32]$$
$$X_4 + d^- - d^+ = 3.78 \quad [33]$$
$$X_5 + d^- - d^+ = 2.072 \quad [34]$$
$$X_6 + d^- - d^+ = 1.2 \quad [35]$$
$$X_7 + d^- - d^+ = 11.7 \quad [36]$$
$$X_8 + d^- - d^+ = 23.4 \quad [37]$$

NO_x Reduction Goal:

$$3X_1 + 4.8X_2 + 1.905X_3 + 3.81X_4 + 18.5X_5 + 1.0X_6 + 73.5X_7 + 294X_8 + d^- - d^+ = 400.515 \quad [38]$$

Subject to constraints

$$X_1 + d^-_{38} - d^+_{38} = 3.0 \quad [39]$$
$$X_2 + d^-_{39} - d^+_{39} = 4.8 \quad [40]$$
$$X_3 + d^-_{40} - d^+_{40} = 1.905 \quad [41]$$
$$X_4 + d^-_{41} - d^+_{41} = 3.81 \quad [42]$$
$$X_5 + d^-_{42} - d^+_{42} = 18.5 \quad [43]$$
$$X_6 + d^-_{43} - d^+_{43} = 1.0 \quad [44]$$
$$X_7 + d^-_{44} - d^+_{44} = 73.5 \quad [45]$$
$$X_8 + d^-_{45} - d^+_{45} = 294 \quad [46]$$

RESULTS:

Vehicle Type	Annual Mileage (km/ yr)	CO_2	CO	HC	NO_x
2 Wheeler (4S)	10,300.00	265	23	6	2.0
3 Wheeler	44,732.80	4599	97	29	3.8
Passenger car	18,372.79	3353	14	0.89	0.905
Taxis	36,286.59	6246	27	0.78	0.81
Multi Utility Vehicle	56,101.47	19061.4	17.5	1.702	17.5
Light Commercial Vehicle	60,630.20	20607	19	0.2	1
Trucks	45,583.20	15455	41	10.7	72.5
Buses	91,313.40	30912	84	23.4	294
TOTAL	3,63,320.45	1,00, 498.40	322.5	72.672	392.515

TABLE 2: Results

CONCLUSION:

The above formulated Lexicographic Goal Programming problem was solved using LINDO and the results obtained are given in the table given above. It is evident from the results that annual mileage and the amount of pollutants coming out from our vehicles can be optimized using Goal Programming. In the beginning the total annual mileage of various kinds of vehicles running on our roads was 2, 62, 000 km/ year which is now increased by 1, 01, 320.45 km which shows about 38.67% increase in distance. The amount of CO_2 emitted was 1,00,507.4 kg/ year which is reduced by 9 kg/ year. The amount of CO has been reduced to 322.5 kg from 331.5 kg, the amount of HC is reduced to 72.672 kg which was initially 81.042 kg and the amount of NO_x has been reduced to 392.515 kg from 400.515 kg.

Although, in the first sight it seems that the amount of pollutants decreased is very less but if see the whole scenario carefully it is very clear that increase in annual mileage leads to increase in amount of pollutants in the space but here these two directly proportional variables have been optimized simultaneously. In a run of 2, 62,000 km the amount of CO_2 was 1,00, 507.4 kg/ year so using simple unitary method in a run of 3,63,320.45 km it should be 1,39,375.55 kg/ year but our result is 1,00,498.40 kg/ year so reduction of 9 kg/ year is apparent change but real change is 38,877.15 kg/ year which is about 38.68% reduction. Similarly we can say that a considerable amount of real change in amount of other pollutants has occurred.

We do not claim that we have controlled air pollution because air is very dynamic in nature and it is impossible to control the components of nature but we have tried to control vehicular emissions and this is a basic study having many dimensions for improvement and further modifications according to the desires of changing time, place and desires of human beings.

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