International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 951-959 www.ijaem.net ISSN: 2395-5252

Optimization of Automobile Mix as a Traffic and Air Pollution Reduction Strategy in Owerri, Nigeria

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Submitted: 15-10-2021 Revised: 26-10-2021 Accepted: 28-10-2021

ABSTRACT
Traffic congestion and control in Nigerian cities have always posed a challenge to stake holders. Yet man's quest for mobility to meet various needs continues to increase. This paper sets out to examine how the application of automobile mix can be a strategy for traffic reduction in Owerri, Nigeria. A field study was conducted in Owerri to ascertain the total passenger requirement, number and mix of passenger vehicles as well as measure three main road transport-induced air pollutants. The result of the field work showed existing commuter vehicles mix of 56.2:63.7: 19.6:1.6:1 for salons, wagons, mini-buses, coaster buses and big buses respectively, out of a total of 85,950 passenger vehicles. The air ambient pollutants level was higher than the recommended standards. A new model was developed to achieve a remix of 10:33:53:14:1 for the same vehicle types and a reduction in volume to 49,665 vehicles, and a reduction of 40 to 50 percent in target air pollutants. The analyses show that mini-buses and coaster buses have advantage over salon cars, wagon vehicles and big buses in terms of traffic congestion control and amount of pollutants released into the environment. The two bus types could be said to have least pollutants released per passenger carried. An optimal vehicle remix, which gives higher priority to these buses has been shown to reduce traffic by 40% and subsequently reduced air pollutants. The paper therefore concludes that vehicular remix of 10:33:53:14:1, for salon: wagon: mini-buses: coaster buses: big buses be adopted for Owerri commuters transportation need. It recommends among other, that governments should adopt regulatory and economic instruments leveraging on disincentive and incentive measures to skew road transportation to the use of mini buses and coaster buses as a deliberate means of reducing traffic congestion in cities.

Key words: Automobile, Traffic, Traffic Reduction, Air Pollution.

I. INTRODUCTION

An automobile is a self propelled vehicle which contains the power source for its propulsion, and is used for carrying passengers and goods on the ground, such as car, bus, truck (Purdy et al, 2020). Wikipedia, (2020) defines it as a wheeled vehicle that carries its own motor. On the other hand, traffic refers to all the vehicles that are moving along the roads in a particular area (CED, 2020). Air pollution is defined as the presence of one or more contaminants in the atmosphere (such as dust, fumes, gas, mist, odors, smoke or vapor) in quantities, characteristics, and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property (Subramani, 2012). Traffic and air pollution reduction is the deliberate effort made to reduce the number of vehicles moving on the roads, and the release of air contaminants into the atmosphere, of an area using various strategies.

Owerri is the capital city of Imo State of Nigeria. It sits at the intersection of roads from Port Harcourt, Onitsha, Aba, Umuahia, Okigwe and Orlu and at latitude 5^o $28^/$ $35.6^{//}$(5.4766^o) North and longitudes 7^o $1^/$ $0.6^{//}$ (7.0168^o) East and elevation of 75m above sea level, (Encyclopedia Britannica, 2009). As the capital city of Imo State of Nigeria, Owerri is growing outwards from the city centre. Over the years, the state government offices, markets, schools, banks and other business offices have been located at about its centre. The city has hitherto been fed with traffic from the main entrance arteries such as Orlu, Onitsha, Port-

Harcourt, Aba, Mbaise and Okigwe roads. Private and public housing projects have developed and continued to develop outwards from the city centre.

The obvious implication of this style of development and the strategic location of Owerri as the eastern heartland is that majority of the people in Owerri have reasons to commute to and fro the city centre from their abodes that are some distances from the centre. One of the consequences of this necessary movement is vehicular congestion with the attendant air pollution from vehicle exhaust emission. Recently, the State Government embarked on an urban renewal programme for the Owerri Capital City with a major component being roadway and junction expansions to accommodate increased traffic in the city.

The vehicles are usually powered by either petrol (gasoline) or diesel internal combustion engines. Such internal combustion engines are known to be major sources of outdoor air pollution, and traffic is the most notable source of air pollution in urban areas, (Cholakov, 2021). The relentless motorization of society has entailed an increasing growth of vehicle emissions which impact negatively on urban air quality.

There is therefore, the need to focus on the optimization of automobile mix that satisfies the mobility needs of Owerri Municipal dwellers, and results in reduced traffic and air pollution owing to exhaust emission.

A road is an identifiable route of travel, usually surfaced with earth, gravel, asphalt or concrete, and supporting land passage by vehicles among others. The most common road vehicle in both the developed and developing world is the automobile. Other users of the road include bicycles and pedestrians and special provisions are sometimes made for each of these. For example, the use of bus lanes gives priority for public transportation and cycle lanes provide special areas of road for bicycles to use. Motor cars offer high flexibility but are associated with high energy and space use, and being the main source of noise and air pollution in cities. Buses allow for more efficient travel at the cost of reduced flexibility. One way of reducing traffic in an area is either to avoid movement, minimize movement or move in the most efficient mode. Optimization of this engineering system, is therefore, required to achieve an efficient mode.

II. REVIEW OF OPTIMIZATION OF TRANSPORTATION SYSTEMS

Generally, optimization is the act of obtaining the best solution under given circumstances (Aravelli, 2014). In traditional optimization procedure, the designs are usually taken at a stretch or all-in-one manner which is non-segmented. This method suits well for problems of moderate size which include a few design variables and constraints. But this is not often the case. Large scale engineering challenges such as design of an airplane or a power plant require the satisfaction of a large number of constraints and contend with design variables. Some of these challenges also have subparts or disciplines that indirectly contribute to the overall convergence of the system. Such multifaceted optimization problems can be easily solved using a different approach, a non-traditional hierarchical decomposition based optimization strategy also known as various levels decomposition.

Borndorfor et al, (1998) while writing on optimization of transportation Systems acknowledged that the world has experienced two hundred years of unprecedented advances in vehicle technology, transport system development, and traffic network extension. They agreed that technical progress continues but seems to have reached some limits. According to them, congestion, pollution and increasing costs have created, in some parts of the world, a climate of hostility amongst transportation technology. Since the need for mobility continues to increase, they concluded that inter disciplinary cooperation is necessary and proposed the application of the theory of optimization to make better use of resources and existing technology.

Davulis and Sadzins, (2010), while discussing modeling and optimization of transportation costs, stated that transportation of passengers and cargo is carried out in a transport system consisting of fixed facilities (roads and railways), the transport means (rolling - stock) that use these fixed facilities and an organizational structure that ensures the efficient use of transport means, fixed facilities and their interface. They added that a model for the distribution of transportation flows assumes that flows of passengers and cargo carried in a transport network must be distributed in such a way that all needs of transport users would be satisfied at the lowest transportation cost. They concluded that an approach based on optimization of transportation flows in any groups has obvious advantages.

While discussing optimization of urban road traffic in Intelligent Transport System, Alina et al, (2012), noted that urban traffic congestions represent a major problem in the vast majority of World Metropolis. They stated that the Intelligent

Transport Systems (ITS) are created to provide real time control and route guidance for the traffic participants, and to optimize the performance of traffic networks. Worldwide, the road traffic phenomenon is more and more difficult to control, coordinate or manage. The apparently chaotic nature of road traffic is by the fact that it is performed by large numbers of moving entities (road vehicles and pedestrians) which are driven by very diverse reasons. This includes scope, destination, distance, urgency, importance and route. They stated that the objective of urban traffic optimization is to increase the efficiency of transportation services and thus their capacity to satisfy user requirements.

From the foregoing, the relevance of optimization as a tool for arriving at veritable decisions in transportation systems planning can be appreciated.

III. METHOD OF ASSESSMENT

Commuters need to move and this movement results in the use of vehicles. The use of vehicles constitutes a major source of traffic. The powering of the vehicles also produces air pollutants. Therefore, the assessment and control strategy of traffic and air pollution should include;

a) Determination of the transport need and
b) The assessment of the resultant traffic of the study area – Owerri Municipal, resulting from the needed movement, and the attendant possible pollutants emission.

The study was carried out at five strategic locations in the Owerri Municipal viz; Imo State University (IMSU) Junction , Amakohia Junction, Assumpta Junction, Emmanuel College Junction and MCC/Wethedral Road Junction. The selected locations for the survey are points with high traffic and business activities. Exhaust emissions of typical vehicles were also measured. The result of the assessment was imputed into a model in terms of vehicle types and exhaust emissions, and optimized for vehicle and emission reductions.

3.1 Determination of Transport Need

The vehicles, (in their various classes), traversing the five strategic locations in the project area were counted over a 12-hour period – 7am to 6p.m. Based on an observed percentage occupancy of the passenger vehicles, the total passenger transportation needs at the five locations was determined. It was observed that these locations record high traffic volumes within the hours of 7.30 – 9.30am (when offices and commercial activities commence) and 4.00 – 7.00pm in the evening at the close of work and market activities.

The time-segmented transportation needs as well as the cumulative transportation needs at the locations were evaluated.

3.2 Measurement of Air Pollutants

Three target air pollutants from exhaust emissions – carbon monoxide (CO), Nitrogen dioxide (NO_2), Hydrocarbons-Methane (CH4) were measured using standard Aeroqual/crowcon Gasman Monitors. Also measured were ambient air contents of same gases at three intervals within 12 hours in a day for a total of two days at each location.

IV. FIELD RESULTS AND ANALYSIS

The vehicle counts for each survey day and measured pollutants were collated and the cumulative figures deduced. Applying the principle of worst case scenario on the collated cumulative vehicles and measured pollutants for the five survey locations yields Tables 1-5

TABLE 1 CUMULATIVE RESULTS FOR IMSU JUNCTION

Period	Cumulative Vehicle Types						Pollutants		
	Sal. Veh. V_1	Wagon Veh. V_2	Mini Buses V_3	Coaster Buses V_4	Big Buses V_5	Trucks V_6	CO Ppm	NO_2 ppm	CH_4 Ppm
Morning (At 7am)	847	833	186	37	22	262	09	18	0.031
Afternoon (At 2pm)	15090	12661	3403	229	78	684	06	0.169	ND
Evening (At 6pm)	25022	20813	4820	357	106	944	14	0.090	ND
Standards							10	0.04-0.06	NS

ND: NONE DETECTED
NS: NOT STATED

TABLE 2 CUMULATIVE RESULT FOR AMAKOHIA JUNCTION

Period	Cumulative Vehicle Types						Pollutants		
	Sal. Veh. V_1	Wagon Veh. V_2	Mini Buses V_3	Coaster Buses V_4	Big Buses V_5	Trucks V_6	CO Ppm	NO_2 ppm	CH_4 Ppm
Morning (At 7am)	754	601	160	08	05	57	7	0.134	ND
Afternoon (At 2pm)	10581	8187	3405	544	70	435	6	0.073	ND
Evening (At 6pm)	16218	15311	5526	645	127	806	8	0.111	ND
Standards							10	0.04-0.06	NS

ND: NONE DETECTED
NS: NOT STATED

TABLE 3 CUMULATIVE RESULT FOR ASUMPTA JUNCTION

Period	Cumulative Vehicle Types						Pollutants		
	Sal. Veh. V_1	Wagon Veh. V_2	Mini Buses V_3	Coaster Buses V_4	Big Buses V_5	Trucks V_6	CO Ppm	NO_2 ppm	CH_4 Ppm
Morning (At 7am)	743	874	229	15	22	75	3.00	0.090	1.00
Afternoon (At 2pm)	11332	11291	2908	275	234	714	11.00	0.087	ND
Evening (At 6pm)	20429	18853	3819	382	357	1727	17.00	0.137	ND
Standards							10	0.04-0.06	NS

ND: NONE DETECTED
NS: NOT STATED

TABLE 4 CUMULATIVE RESULT FOR EMMANUEL COLLEGE JUNCTION

Period	Cumulative Vehicle Types						Pollutants		
	Sal. Veh. V_1	Wagon Veh. V_2	Mini Buses V_3	Coaster Buses V_4	Big Buses V_5	Trucks V_6	CO Ppm	NO_2 Ppm	CH_4 Ppm
Morning (At 7am)	1498	2816	527	89	60	180	80.00	0.073	1.00
Afternoon (At 2pm)	11154	11635	6706	473	316	584	22.00	0.092	ND
Evening (At 6pm)	34101	38368	11921	953	607	1697	13.00	0.182	1.00
Standards							10	0.04-0.06	NS

ND: NONE DETECTED
NS: NOT STATED

TABLE 5 CUMULATIVE RESULT FOR WETHEDRAL/MCC JUNCTION

Period	Cumulative Vehicle Types						Pollutants		
	Sal. Veh. V_1	Wagon Veh. V_2	Mini Buses V_3	Coaster Buses V_4	Big Buses V_5	Trucks V_6	CO Ppm	NO_2 Ppm	CH_4 Ppm

Morning (At 7am)	1108	2353	112	18	24	86	22.00	0.075	ND
Afternoon (At 2pm)	16151	15702	379	62	85	316	17.00	0.084	ND
Evening (At 6pm)	30647	23098	883	164	195	633	21.00	0.126	ND
Standards							10	0.04-0.06	NS

ND: NONE DETECTED
NS: NOT STATED

4.1 Exhaust Emission of vehicles.
The representative vehicles exhaust emissions for the three pollutants of interest are presented on Table 6.

Table 6 Exhaust Emission of Different Vehicles

VEHICLE	**POLLUTANTS**		
	CO, ppm	**NO_2, ppm**	**CH_4, ppm**
Car 1	234.30	0.56	284.00
Car 2	234.30	0.30	5613.00
Car 3	234.30	0.60	4227.00
Average	**234.30**	**0.49**	**4229.00**
Wagon 1	173.80	0.93	79.00
Wagon 2	68.80	0.49	87.00
Wagon 3	234.30	0.04	79.00
Average	**158.97**	**0.49**	**81.67**
Mini Bus 1	234.30	0.28	3797.00
Mini Bus 2	234.30	0.22	4461.00
Mini Bus 3	209.20	0.15	512.00
Average	**225.93**	**0.22**	**2923.33**
Coaster Bus 1	234.30	0.63	479.00
Coaster Bus 2	234.30	0.63	444.00
Coaster Bus 3	234.30	0.63	396.00
Average	**234.30**	**0.63**	**439.67**
BigBus 1	ND	5.37	14.00
BigBus 2	76	5.37	14.00
BigBus 3	50	5.37	10.00
Average	**42**	**5.37**	**12.67**
Truck 1	254.60	1.03	18.00
Truck 2	246.80	1.26	16.00
Truck 3	254.60	1.27	20.00
Average	**252.00**	**1.19**	**18.00**

4.2 Commuters Traversing the Junctions

The total commuters traversing the survey locations is the product of the number of vehicles and their weighted carrying capacities. From field observations the vehicles were averagely 60% loaded such that the following weighted capacities are derived (see Table 7).

Table 7 Passenger carrying capacity of vehicles

Vehicle Type	Design Capacity	Weighted Capacity
Saloon Vehicles	5	3
Wagon Vehicles	8	5
Mini Buses	15	9
Coaster Buses	33	20
Big Buses	53	32

Using the weighted carrying capacities and the cumulative vehicles accessing the locations, the total commuters traversing the locations are calculated as shown in Tables 8, 9, 10, 11 and 12 respectively.

Table 8 Total Commuters Traversing IMSU Junction in a 12-Hour Day

Veh. Types	Cumulative No	Weighted Capacity	Total Commuters
Saloon Veh. V_1	25022	3	75,066
Wagon Veh. V_2	20813	5	104,065
Mini Buses V_3	4820	9	43,380
Coaster Buses V_4	357	20	7,140
Big Buses V_5	106	32	3,392
Total	**51,118**		**233043**

Table 9 Total Commuters Traversing Amakohia Junction in a 12-Hour Day

Veh. Types	Cumulative No	Weighted Capacity	Total Commuters
Saloon Veh. V_1	1621	3	4863
Wagon Veh. V_2	1531	5	7655
Mini Buses V_3	5526	9	49734
Coaster Buses V_4	645	20	12900
Big Buses V_5	127	32	4064
Total	**9450**		**79,216**

Table 10 Total Commuters Traversing Assumpta Junction in a 12-Hour Day

Veh. Types	Cumulative No	Weighted Capacity	Total Commuters
Saloon Veh. V_1	20429	3	61,287
Wagon Veh. V_2	18853	5	94,245
Mini Buses V_3	3819	9	34,371
Coaster Buses V_4	382	20	7,640
Big Buses V_5	357	32	11,424
Total	**43,840**		**208,987**

Table 11 Total Commuters Traversing Emmanuel College Junction in a 12-Hour Day

Veh. Types	Cumulative No	Weighted Capacity	Total Commuters
Saloon Veh. V_1	34101	3	102303
Wagon Veh. V_2	38368	5	191,040
Mini Buses V_3	11921	9	107,289
Coaster Buses V_4	953	20	19,060
Big Buses V_5	607	32	19,424
Total	**85,950**		**439,916**

Table 12 Total Commuters Traversing Wethedral/MCC Junction in a 12-Hour Day

Veh. Types	**Cumulative No**	**Weighted Capacity**	**Total Commuters**
Saloon Veh. V_1	30647	3	91,941
Wagon Veh. V_2	23098	5	115,490
Mini Buses V_3	883	9	7,947
Coaster Buses V_4	164	20	3,280
Big Buses V_5	195	32	6,240
Total	**54,987**		**224,898**

Of the five junctions investigated Emmanuel College Junction recorded the highest number of vehicles and commuters traversing, and highest values of ambient air pollutants. Further studies will therefore be based on the results from it, as a worst case scenario.

Table 13 shows the total contribution of the three pollutants of interest into the environment by the vehicles traversing the Emmanuel college junction within 12 hours of the day.

Table 13 Total Pollutants Contribution of Vehicles that Accessed Emmanuel College Junction.

Veh. Types	**Total Veh.**	**Carbon Monoxide**		**Nitrogen Dioxide**		**Methane**	
		Rate	**Total x 10^3 ppm**	**Rate**	**Total x 10^3 ppm**	**Rate**	**Total x 10^6 ppm**
Saloon Cars V_1	34101	234.3	7989.86	0.49	16.71	422.9	144.21
Wagon Veh. V_2	38368	158.97	6099.36	0.49	18.80	81.67	3.13
Mini Buses V_3	11921	225.93	2693.31	0.22	2.622	2923.33	34.85
Coaster Buses V_4	953	234.30	223.29	0.63	0.6	439.67	0.42
Big Buses V_5	607	42	5.49	5.37	3.26	12.67	0.0077
Total	85,950		17,031.29 x 10^3 ppm		41.992 x 10^3 ppm		182.62 x 10^6 ppm

4.3 Model Development

The aim of the model is to achieve a remix of the vehicles such that the total commuters of 439,916 are served with a reduction in number of vehicles and pollutants released into the environment. This can be obtained by optimizing the model equations given below;
Solving the Objective function

$3v_1 + 5v_2 + 9v_3 + 20v_4 + 32v_5 = 439916$ (from table 11) 1

Subject to:

For a 40% reduction in CO,

$234.3v_1 + 158.97v_2 + 225.93v_3 + 234.3v_4 + 42\ v_5 = 10{,}218.774 \times 10^3$ 2

For a 50% reduction in NO_2,

$0.49v_1 + 0.49v_2 + 0.22v_3 + 0.63v_4 + 5.37v_5 = 20.996 \times 10^3$ 3

For a 50% reduction in CH_4,

$4229v_1 + 81.67v_2 + 2923.33v_3 + 439.67v_4 + 12.67v_5 = 91.31 \times 10^6$ 4

That 80% of the commuters use buses

$0 + 0 + 9v_3 + 20v_4 + 32v_5 = 351{,}933$ 5

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 10 Oct 2021, pp: 951-959 www.ijaem.net ISSN: 2395-5252

In Matrix form the five equations are thus;

V_1	V_2	V_3	V_4	V_5	
3	5	9	20	32	439,916
234.3	158.97	225.93	234.3	42	10,218,774
0.49	0.49	0.22	0.63	5.37	20,996
4229	81.67	2923.33	439.67	12.67	91,310,000
0	0	9	20	32	351,933

Solving the matrix using Tora Equation Solver yields;
V_1 = 4,278.05, V_2 = 15,029.77, V_3 = 23,688.8, V_4 = 6,220.14, V_5 = 447.85

Table 14 Total Commuters Provided for by the New Scheme

Veh. Types	**Number of Vehicle**	**Weighted Capacity**	**Total**
Saloon Veh. V_1	4,278	3	12,834
Wagon Veh. V_2	15,050	5	75,150
Mini Buses V_3	23,689	9	213,201
Coaster Buses V_4	6,220	20	124,400
Big Buses V_5	448	32	14,336
Total	**49,665**		**439,921**

Table 15 Total Pollutants Emission by the New Scheme

Veh. Type	**Total No.**	**Carbon Monoxide**		**Nitrogen Dioxide**		**Methane**	
		Rate	**Total x 10^3**	**Rate**	**Total x 10^3**	**Rate**	**Total x 10^6**
Saloon Cars V_1	4,278	234.3	1002.335	0.49	2.096	4229	18.092
Wagon Veh. V_2	15,030	158.97	2389.32	0.49	7.365	81.67	1.228
Mini Buses V_3	23,689	225.93	5,352.056	0.22	5.212	2923.3 3	69.251
Coaster Buses V_4	6,220	234.30	1,457.35	0.63	3.919	439.67	69.251
Big Buses V_5	448	42	18.816	5.37	2.406	12.67	2.735
Total	**49,665**		**10,219.88 X 10^3**		**20.998 X 10^3**		**91.312 X 10^6**

Table 14 shows a total of 49,665 vehicles for the cumulative commuters of 439,921 as against 85,950 vehicles for 439,916 commuters in Table 11. This amounts to a reduction of 36,285 vehicles or 42.22% in passenger traffic volume.

Table 15 shows exhaust emissions of 10,219,880 ppm of Carbon monoxide, 20,998ppm of Nitrogen dioxide and 91,312,000ppm of Methane as against 17,005,800ppm, 41,992ppm and 182,620,000ppm respectively in Table 13. These amount to 40% reduction in Carbon monoxide, 50% reduction in Nitrogen dioxide and 50% reduction in Methane, owing to exhaust emissions of passenger vehicles.

V. DISCUSSION

As can be seen from Table 11, the analyses of the field data revealed a typical existing passenger vehicle mix of; 34,101:38,368: 11,921: 955: 607, totaling 85,950 for salon vehicles: wagon vehicles: mini buses: coaster buses: big buses for a total of 439,916 commuters. The ratio can, therefore, be written as 56.2: 63.7: 19.6 : 1.6 :1

The analysis also shows a very high volume of 72,469 vehicles out of 85,950 or 84.3% of low-passenger carrying capacity vehicles (salons and wagons).

The new scheme developed has the following corresponding ratio;

4,278 : 15, 050 : 23, 689 : 6, 220 : 448 for 439,921commuters which is a little more than the figure from Table 14.This ratio is 9.5 : 33.6 :52.9 : 13.9 : 1.
This is now tilted to favour the high-passenger-carrying vehicles while taking into account pollutants release by them. In the new scheme, the low-passenger-carrying vehicles now total only 19,328 vehicles out of 49,665 amounting to 38.9%

The new scheme reduces passenger vehicles by 36,285, from 85,950 to 49,665 representing 42.2%, for little more commuters, and less pollutants emission.

VI. CONCLUSION

This paper set out to achieve an optimum automobile mix that satisfies the mobility needs of Owerri Municipal dwellers and achieve reduced traffic and air pollution in the city. The result of the field work showed existing commuter vehicles mix of 56.2:63.7: 19.6:1.6:1 of salons, wagons, mini-buses, coaster buses and big buses respectively, of a total of 85,950, and ambient air pollutants higher than recommended standards. The model developed achieved a remix of 10:33:53:14:1 of same vehicular types and reduction in traffic volume by 42% and target air pollutants of about 40-50 percent.

6.0 Recommendations

To achieve the desirable results of this research, it is recommended that government should adopt regulatory and economic instruments anchored on disincentive and incentive measures. Specifically government should;

1. sensitize the populace on the need for a sustainable transportation policy.
2. introduce bus lanes on major roads (Orlu, Okigwe, Wethedral, Asuumpta, Egbu, Douglas), which give access to buses only thus reducing the trip time of buses
3. increase licensing fees for salons and wagons
4. encourage private-private or public-private, cooperation in the public bus transportation system with grants.
5. introduce annual parking fees for cars and wagons.
6. out rightly ban the use of such low-carrying capacity vehicles as salons and wagons for commercial purposes particularly on some major roads where bus lanes have been suggested.

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