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# A review of the history of emission legislation, urban and national transport trends and their impact on transport emissions

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## Abstract

With CARB's proposals for the introduction of ZEV's in California fast approaching, and no significant steps forward in terms of the battery technology necessary to make this reality, do the politicians, public, pressure groups and manufacturers need to re-address the aims and methods for reducing the environmental impact of transport systems. This paper will review the trends in transport and the effects of this on harmful emissions, it will then go on to discuss the issue of who is responsible for the current direction of emission reduction for road vehicles, whether or not this approach has been successful, and who should take the responsibility for any further plans.

The authors feel that the current legislative focus on vehicle emission reduction is not enough on its own and that an integrated approach to transport management of all types is needed if the environmental impact of total transport systems is to be reduced.

## 1. Introduction

The approach by government to combating the problem of environmental damage caused by vehicle exhaust has been to introduce ever more stringent vehicle emission limits. This trend has been led by the USA with California taking the most significant role. Current legislated limits for spark ignition engines in the USA and Europe require the use of three way catalytic converters and stoichiometric fuel strategies. The use of this strategy can reduce emissions of exhaust pollutants by up to 90%, but efficiency is strongly dependant on operating conditions [1] .

The benefits of this strategy have been in some way masked by the large increase in car numbers and use at the expense of other forms of mass transport such as buses and trains.

## 2. The History Emission Control

### 2.1 Emission Control in the USA

The problem of urban smog in some cities prompted the American government to introduce exhaust emission limits for CO and HCs as part of the 1968 Clean Air Act. This set emission levels at 30-40% of the estimated uncontrolled levels of 1967 and established the Environmental Protection Agency (EPA) to administer and enforce the limits. Emissions of $NO_x$ were added in 1973 and the levels for CO and HCs were reduced to 10% of the original 1968 levels.

As each deadline approached the automotive industry would claim that there was no known technology available to meet the proposed limits. Thus when the target date arrived and the limits could not be met, the introduction date would be postponed and interim standards set. The original 1975 standards for CO and HCs were not reached until the 1981 model year and the $NO_x$ standards, with the exception of California, had still not been met in 1992 [2].

In 1990 a new Clean Air Act was agreed and passed. This included two tiers of standards for future exhaust emissions. Tier I, to be phased in between 1994 and 1998, aimed to reduce HC emissions by 30% and $NO_x$ emissions by 60% (Table 1).

**Table 1.** US Emissions Limits for Spark Ignition Engines (Except California) [3]

| Emissions (g/km) | Durability (km) | MY 1991 | Tier I | Tier II |
|---|---|---|---|---|
| **NMHC** | 80,000 | 0.255 | 0.155 | 0.078 |
| | 160,000 | NA | 0.193 | 0.078 |
| **CO** | 80,000 | 2.113 | 2.113 | 1.057 |
| | 160,000 | NA | 2.610 | 1.057 |
| **$NO_x$** | 80,000 | 0.622 | 0.249 | 0.124 |
| | 160,000 | NA | 0.373 | 0.124 |

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For a vehicle manufacturer to be able to sell in the US, 40% of their sales volume must comply with the regulations by 1994, 85% by 1995 and 100% thereafter. In addition to this the EPA can require manufacturers to recall models that fail to meet the standards in customer use. In-use standards, the same as those for certification, will be phased in between 1996 and 1998. Emission control durability has been doubled from 80,000 km to 160,000 km and applies to certification and in-use standards.

Final Tier II standards are yet to be set. In the year 2000 the EPA will assess the need for further reductions in emission limits and whether the technology required is available and cost effective. If the EPA make no formal decision, standards contained in the 1990 Act, allowing for a 50% reduction of Tier I standards, will come into effect automatically from the year 2003.

## 2.11 California

Until 1993 the emission standards in California were the same as those in the rest of the USA. In 1993 the Californian Air Review Board (CARB) put forward it's own emission standard proposals. This involved the phasing in of progressively lower emission vehicles until, in 1998, zero emission vehicles would be introduced. Any vehicle manufacturer wanting to sell in California must introduce vehicles that meet the emission limits in table 2 following the steps shown in figure 1.

**Table 2.** Californian Emission Standards [3]

| **Emission (g/km)** | **Durability (km)** | **MY 1993** | **TLEV** | **LEV** | **ULEV** | **ZEV** |
|---|---|---|---|---|---|---|
| **NMOG** | 80,000 | 0.4 | 0.2 | 0.12 | 0.06 | 0 |
| | 160,000 | 0.5 | 0.25 | 0.14 | 0.09 | 0 |
| **CO** | 80,000 | 5.44 | 5.44 | 5.44 | 2.72 | 0 |
| | 160,000 | 6.72 | 6.72 | 6.72 | 3.63 | 0 |
| **$NO_x$** | 80,000 | 0.64 | 0.64 | 0.32 | 0.32 | 0 |
| | 160,000 | 1.6 | 0.96 | 0.48 | 0.48 | 0 |

Notes: MY = Model Year, TLEV = Transitional Low Emission Vehicle, LEV = Low Emission Vehicle, ULEV = Ultra Low Emission Vehicle, ZEV = Zero Emission Vehicle

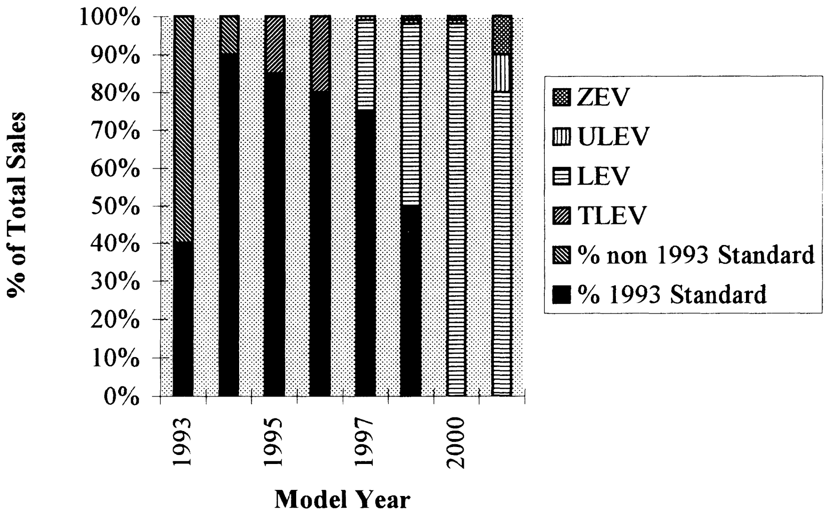


**Figure 1.** The Proposed Timetable for the Introduction of New Emission Standard Vehicles in California

## 2.2 Emission Control in Europe

In 1956, the German Parliament asked the Association of German Engineers to develop general guidelines for a reduction in air pollution, including vehicle exhaust emissions [4]. At around the same time the French started a similar programme of research. These programmes were partly prompted by work carried in California on how to reduce the smog problem there. Some French and German cities had similar air quality problems and found the Californian results encouraging. From 1961 onwards the two teams worked closely on the problem of vehicle exhaust emissions. In 1970 the EC introduced the first vehicle emission limits based on the work of the French and Germans. By 1982 the emission levels for all controlled emissions were around 50% of the original 1970 levels.

In 1982 the EC Commission decided to rationalise further legislation and to take a "Global Approach" in further decisions. This meant assessing all the possible effects of the various solutions before making a final decision. This was known as the "Evolution of Regulations - Global Approach" or ERGA for short. ERGA 1 was set up in 1982 to assess the health effects of vehicle exhaust, the various emission control technologies and resulting economic and environmental costs.

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ERGA 1 found that in the EEC 70% of atmospheric CO, 20-50% of $NO_x$ and 20-40% of HC emissions were from vehicles at national level [5]. Its conclusion was that it was difficult to define an absolute threshold level for each pollutant and that the best approach would be to establish limits that were both desirable and attainable. They also carried out cost/benefit analysis of a number of different emission control measures. The conclusion of this was that a combination of lean burn technology, multi point fuel injection and oxidation catalyst technology presented the most promising future. This contrasted with the American approach of three way catalysts, which were felt to more costly and unproven in European conditions.

Meanwhile in Germany, press reports of damage to forests attributed the cause to pollution from vehicle exhaust. This resulted in a public outcry and put pressure on the German government to act. In reply to this the government announced that it would introduce vehicle emission standards similar to those in America. This in turn forced the EC Commission to act to maintain harmony with the other member states. This involved the introduction of unleaded petrol and a move towards the American philosophy of using three way catalysts and culminated in directive 91/441/EEC which set limits equivalent to those found in America. Table 3 shows the emission limits set out in this directive. Currently only vehicles fitted with a three way catalytic converter can achieve these limits.

**Table 3.** Directive 91/441/EEC Emission Limits [6]

| Introduction Date | CO (g/km) | HC + $NO_x$ |
|---|---|---|
| **31/12/92** | 2.72 | 0.97 |
| **1/1/96** | 2.2 | 0.5 |

## 3. Transport Trends

Since 1950, when vehicle registrations in the UK numbered 2 million, the numbers of vehicles has grown such that by 1990 the equivalent figure approached 20 million [7], a ten fold increase. As the ownership and use of vehicles powered by internal combustion engines has increased so the effects of their exhaust has become more noticeable, resulting in photochemical smogs and increased health problems on particularly bad days.

In addition to the increasing numbers of vehicles there has been an increase in vehicle use particularly in urban areas. Table 4 shows the increase traffic volume in London over the ten year period between 1981 and 1991 [8]. The number of journeys using cars and total journeys have increased by 25% and 24%

respectively with only the use of motorcycles decreasing. The trend is similar in other countries.

**Table 4.** A Comparison of Traffic Volume per Day Across a Boundary by Vehicle Type in London Between 1981 and 1991 [8]

| Vehicle Type | 1981 (Thousands) | 1991 (Thousands) | % Difference |
|---|---|---|---|
| Cars | 202 | 253 | 25 |
| Taxis | 1 | 1 | 0 |
| Goods | 35 | 47 | 34.3 |
| Total | 245 | 304 | 24.1 |

This is compounded by the fact that as the numbers increase so congestion also increases. Congestion results in a decrease in speed over the journey and thus increases the vehicle emissions per journey. In 1968 the average speed of London traffic was 19.33 mph compared to 17.36 mph in 1994 [8]. Congestion is also extremely costly, one study calculated that congestion cost the UK 3.2% of it's GNP and the USA 1.3% GNP [9]. A review of the period 1982-1990 showed that urban congestion in 50 of the USA major cities increased by 20%.

Table 5 shows that private personal transport, i.e. the car, is the most favoured means of transport for urban trips. Almost 50% of trips in London are done as either a driver or passenger of a car. This is compared with 24.5% by all forms of public transport. It would also appear that car users tend not to travel far and prefer to travel alone. Up to 75% of car trips in London are less than 9km in length and only 23% of them have more than one occupant[8].

**Table 5.** Forms of Transport used for Trips in London

| Form of Transport | % of Trips |
|---|---|
| Car Driver | 36.1 |
| Car Passenger | 13.0 |
| Public Bus | 9.4 |
| Underground | 8.5 |
| B.R. Train | 6.5 |
| Van/Lorry | 4.0 |

Note: Total trips = 20,610,000 per year

The use of roads and the demand for passenger transport has increased dramatically in the last 40 years. Department of Transport figures (figure 2) show that the number of passenger kilometres travelled in the UK has increased by 214% between 1952 and 1994 from 219 Billion to 689 Billion [10]. It also shows that the vast majority of this is due to an increase of road use, and further, that this is primarily due to an increase in the use of cars. In the same period the use of cars showed a ten fold increase from 58 Billion in 1952 to 596

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Billion in 1994. The use of public forms of transport, i.e. buses and trains, has dropped significantly. In 1952 60% of all passenger km were done by public transport, 42% by bus and 18% by rail. By 1994 the total had dropped to just 11%, 6% by bus and 5% by train.

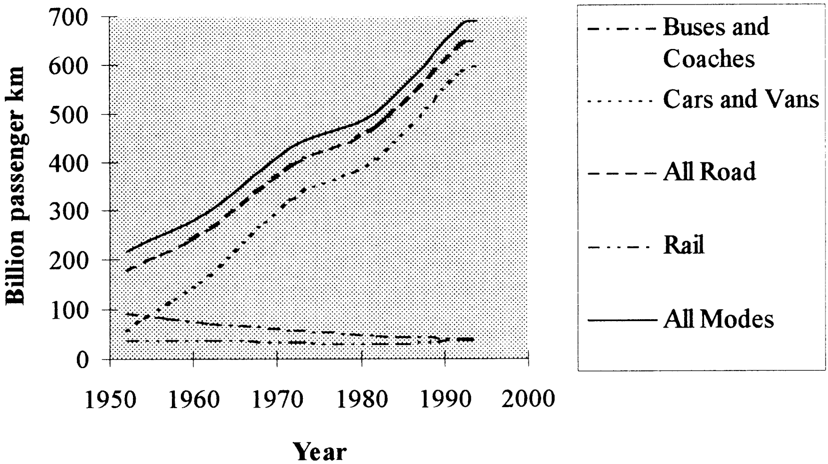


**Figure 2.** Passenger Transport by Mode in the UK from 1952-1994

Table 6 shows the increase in vehicle traffic over a ten year period from 1983 to 1993 in a number of different countries around the world. Japan has the most significant increase. For example, the use of cars alone in 1993 was 45% higher than the total recorded in 1983. This shows the same trend of increasing vehicle use, particularly of cars, world wide.

**Table 6.** A Comparison of Road Traffic (Billion Vehicle km) by Type [10]

| | Year | Great Britain | France | Germany | Japan | USA |
|---|---|---|---|---|---|---|
| **Cars and Taxis** | 1983 | 231.2 | 258.1 | 304.4 | 259.7 | 1966.4 |
| | 1993 | 336.8 | 333.5 | 464.9 | 405.7 | 2798.7 |
| **Goods Vehicles** | 1983 | 44.9 | 11.9 | 33.3 | 199.3 | 657.4 |
| | 1993 | 64.7 | 15.2 | 55.4 | 265.4 | 871.6 |
| **Buses** | 1983 | 3.7 | 1.8 | 3.3 | 6.2 | 10.9 |
| | 1993 | 4.6 | 2.2 | 4.7 | 7.1 | 9.9 |
| **Total** | 1983 | 288.1 | 275.8 | 348.2 | 285.2 | 2654.0 |
| | 1993 | 410.3 | 357.4 | 536.6 | 678.2 | 3696.0 |

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## 4. Impact of Growth on Transport Emissions

As stated previously some components of vehicle exhaust can have a deleterious effect on the environment and health. Figure 3 shows the impact of the increases in demand for transport on the emissions of the main pollutants in the UK [10].

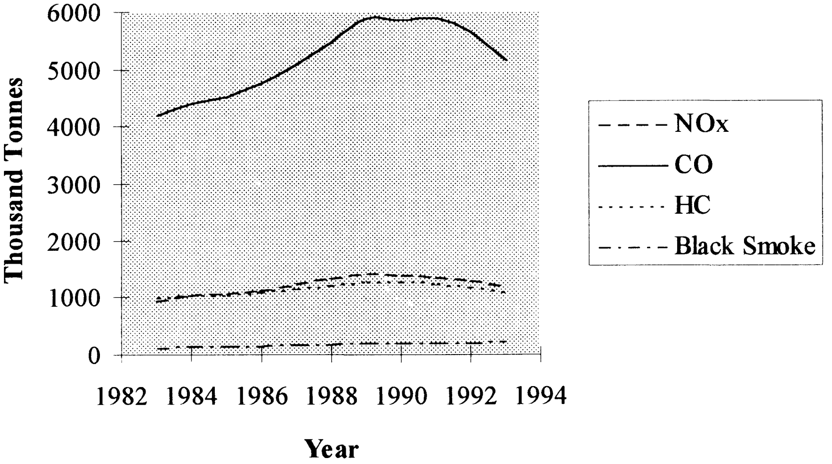


**Figure 3.** Emission of Regulated Exhaust Pollutants from Road Transport in the UK

Emissions of the three main pollutants, i.e. $NO_x$, HC and CO increased steadily to a peak in 1989 after which levels began to drop. The increase can be attributed to the increased use of cars and journey's over the same period. However, comparison between figure 2 and 3 show that road use increased at a greater rate than emissions from road use. This can be attributed to the increased efficiency of vehicles during this time because of greater use of electronic engine management and fuel injection systems. Emissions of $NO_x$, HC and CO began drop in 1989 and have continued to do so. This is against the upward trend in vehicle numbers and road use. This can be mostly explained by the introduction of three way catalytic converters at around this time, but also the increase in numbers of diesel powered vehicles which produce less HCs and CO. Only the emissions of black smoke have continued to increase which can be attributed to the greater numbers of passenger cars being diesel powered. Emissions of $CO_2$ from vehicles have continued to rise due to increasing numbers. In the period from 1971-1991 $CO_2$ from road traffic has increased by 87.5%, an average of 4.1% a year.

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## 5. Discussion and Conclusions

It is clear that in the past government has played the most significant role in the reduction of the effect transport has on the environment. It is also clear that the primary focus of this effort has been concentrated on reducing emissions of individual vehicles culminating in the introduction of ZEVs in California by 1998. The observed drop in levels of controlled emissions after the introduction of three way catalysts in the UK show that this method of reducing the impact of vehicle exhaust can be effective. However, cities like Los Angeles still have a serious air quality problem even after 25 years of similar measures.

Although the observed reductions are a step in the right direction they can be seen to be fairly small. To make a significant inroad on the overall emissions from vehicles the primary focus should be the number of cars on the road and the journeys they make. By removing a vehicle from the road it's emissions are reduced by 100% and, in addition to this congestion will be reduced making the remaining traffic more efficient.

As it stands governments are reluctant to introduce measures that will reduce traffic. Cars are often perceived to be a measure of status and an example of individual freedom, while this image exists it makes it very risky for politicians to act against it.

The legislators need to have a rational long term objective of reducing road traffic, particularly in urban areas. What methods they use for achieving this need to be decided amongst all the interested parties, i.e. politicians, pressure groups, vehicle manufacturers and the public. What ever decisions are made must be the result of proper objective research that is removed from the vested interests of the individual parties. They should aim to take an integrated look at the development of new, more efficient and environmentally friendly, urban transport systems. This should include measures to reduce demand for transport, incentives for using other forms of transport and penalties or restrictions for using cars inefficiently.

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