DOWNSIZING POWER AND SPEED, THE SAFE ROAD TO FUEL ECONOMY, ROAD SAFETY AND SUSTAINABILITY

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SUMMARY

The power and speed of cars, trucks and motorcycles are unnecessarily high. Enforcing motorway speed limits and setting lower speed limits are effective instruments for reducing fuel consumption and emissions and improving road safety. The trend towards more powerful engines and higher performance must be halted if the desired reduction in CO_2 emissions and the desired improvement in fuel efficiency and traffic safety are to be achieved. Specific power ratings need to be halved at least and performance levels need to be reduced substantially if future vehicles and traffic are to be "sustainable". The "Car of the Future" can embody every reasonable consumer feature such as interior space, comfort, safety and image profile, but - to be sustainable - its engine power, performance and weight need to be reduced. Putting "less of the same" into a new generation of vehicles - instead of putting more (technology toys and performance) into them - is a promising, safe and cost-effective route towards real fuel economy, safety and sustainability.

Introduction

Traffic is one of the main causes of the most serious environmental problems world wide, such as acidification, photochemical air pollution, climate change, local air quality and noise levels. When assessed against the criterion of "sustainable development" introduced by the Brundtland Commission and in the light of the concepts of sustainability and safety [1], and given road traffic's total dependence on oil, the current transport system is clearly environmentally *unsustainable*. Above all, growth is the problem. Assuming that the number of vehicles will rise to over one billion worldwide within two decades, and taking into account its contribution to CO_2 emissions and the refering to the Kyoto agreement, the consumption of oil by the Transport sector will have to fall sharply. In addition to curbing car use - an illusion at current fuel prices - the only effective measure is a forced decline in the average fuel consumption per vehicle per km of at least 50% between now and 2010. This seems a feasible target if technical vehicle improvements are geared more towards fuel efficiency instead of upgrading power, performance and weight and if, at the same time, driver behaviour could be guided towards fuel efficiency and away from speeding and strong acceleration. Recent research projects in the Netherlands show that a combined approach of downsizing power and speed, enforcing speed limits and in-car guidance of drivers' behaviour can achieve a 50% reduction target. How can this be integrated into future road safety and environment policy?

Speed, emissions, fuel consumption and other vehicle characteristics

Speed kills. But what is the effect of speed to the environment? It is widely known that fast driving speeds up fuel consumption. Nevertheless, little is known about the overall environmental and fuel efficiency effects of reducing vehicle speeds in various degrees through

enforcing and lowering speed limits in various ways. This question has been targeted in a recent research project in the Netherlands into the costs and benefits of speed limit enforcement and of reducing speed limits [2]. Reducing speeds through strict enforcement or through introducing intelligent, in-car speed-retarding systems and downsizing the performance levels of cars will yield large benefits to society at large. Up to 1% of GNP could be saved, according to this study, if speed limits are fully enforced and optimised to their maximum effectiviness, giving overall CO_2 emission and fuel consumption reductions of up to 30 % and risk reductions of up to 40 %. Thus current Dutch climate change policy target for passenger cars (CO_2 :-10% by 2010) could be achieved by enforcing and lowering speed limits alone.
Table 1 shows the potential effects of these approaches.

Table 1: Direct and indirect effects of lower speed limits and optimised enforcement

Parameters Base index	Base = current limits (1995)	Improved enforcement	Optimum in-car enforcement plus lower speed limits	
			Average	High
VMT	100	94	91	86
Energy	100	89	79	68
CO_2	100	89	79	68
NO_x	100	85	64	48
Casualties	100	85	83	73
Fatalities	100	79	75	60
Travel time	100	99	99	98

The connection between vehicle design and speed on the one hand and emissions and fuel consumption on the other has been examined in detail [3], showing the following correlations (though exceptions occur in practice). In so far as these lead to avoidable effects (extra emissions or fuel consumption), they should be given priority in abatement policies designed to achieve optimum cost/benefit ratios.

A. *Vehicle weight ---- fuel consumption/CO_2 emissions*
Large, heavy cars consume more fuel than small, lighter ones. Heavier vehicles require a higher power output for the same performance, especially when accelerating and under urban driving conditions

B. *Cylinder capacity/power/performance ---- fuel consumption/CO_2 emissions*
Cylinder capacity, maximum power, acceleration capacity, top speed, and, above all, the specific power rating (kW/kg) are significant indicators for fuel consumption and CO_2 emissions. The largest engines and highest power and performance ratings tend to be found in the heaviest vehicles. High-powered (petrol) cars consume more fuel - other things being equal - than those with smaller engines.

C. *Speed ---- fuel consumption/CO_2 emissions/NO_x emissions*
Above about 60 - 70 km/hour, fuel consumption, CO_2 emissions and NO_x emissions increase. Above about 80 km/hour in the case of goods vehicles and about 100 km/hour in the case of private cars, the increase begins to rise faster on account of the increase in air resistance. On average, a modern 1,100 kg car requires a power output of less than 30 kW to travel at 120 km/hour.

D. *Driving habits ---- fuel consumption/CO_2 emissions/ other emissions*
Consumer surveys and car tests show that the difference in fuel consumption between a "racy" and an economical driving style can be over 40%.
A "racy" or "aggressive" driving style with frequent accelerations and braking

also causes a sharp and even extreme increase in CO, C_xH_y and NO_x emissions.

E *Speed ---- accidents and fatalities*

Accident frequencies and fatality rates increase more than proportionally when speed levels increase, especially above a given speed limit. Passive safety features such as crush zones are most effective at lower speeds that triggered their design. The so-called safe German Autobahns without a general speed limit, are twice as unsafe as the Dutch highways with a mixed speed limit system of 100/120 km/hour.

The above shows that there is a significant causal relationship between fuel consumption, CO_2 emissions and emissions of NO_x, CO and C_xH_y on the one hand and vehicle design features such as weight, specific power, performance, and behaviour patterns (speed and acceleration) on the other. TNO Motor Vehicles Test Lab concludes that **optimum speed**, with the lowest emissions and fuel consumption, is between 60 and 80 km/hour for goods vehicles and between 70 and 90 km/hour for private cars. Thus, reducing the power and speed of vehicles is highly effective in attaining environmental as well as road safety goals.

Road safety: the hidden power< >risk paradox

In the USA a fierce battle has been going on concerning the (assumed) lack of safety of small and fuel efficient cars in connection with the possibility of achieving further energy savings by means of body downsizing [4]. As regards *passive safety*, there is indeed a general statistical connection between vehicle weight and risk. But accident statistics do not prove that large, heavy cars are intrinsically safe. Collision tests and statistics from, inter alia, the US Highway Loss Data Institute (HLDI) and the Swedish Folksam [5] prove that in practice it is not weight or size that determines risk, but the quality of the safety structures and, above all, the vehicle's "character" in terms of (too much) power, performance, roadholding and "macho" image. Vehicles in the same weight class perform very differently in both collision tests and accident statistics. In German statistics the highest risks occur not only in the structurily unsafe category of very small cars (minis) designed in the 50s and 60s, but also in the category of the latest fast sports cars, with twice the weight, such as the Audi Quattro and BMW M3.
What is the reason for this?

The *active safety* of private cars has increased significantly in recent decades thanks to improvements in vehicle design. In this connection, a paradoxical phenomenon, which can be explained in terms of *compensatory behaviour*, occurs: the so-called *"ABS effect"*. German experiments revealed that, contrary to expectations, a disproportionate number of cars with an anti-blocking system were involved in accidents. Apparently, the perception of extra safety removes inhibitions characteristic of a safe, defensive driving style. Available insurance statistics [5] show that cars with perfect road-holding and a high power rating are involved in accidents to a disproportionate degree, especially sports cars and Mercedes, BMW and SAAB models, which achieve high scores for both active and passive safety. In the USA, the two-door (first generation) SAAB 900 - usually a Turbo - has been found to be three times as unsafe for its drivers as the four-door model, whereas the passive safety of both is the same. In conjunction with specific driver characteristics such as age (young) and sex (male), this aspect resulted in recorded risk variations in the USA of up to 800% within the same weight category (see table 2).

The obvious conclusion is that, in the case of fast cars, design features (such as character, performance, perfect active safety features, airbags and sophisticated crash testing) in conjunction with psychological factors, such as overestimation of one's own abilities and risk compensation, lead to a high level of *active unsafety*. Since the new car fleet average top speed is now up to 190 km/hour, this phenomenon is true for all cars except real minis.
Indeed, some cars must be regarded as "killers", especially large and heavy cars (such as 4WD and pick-ups) and “muscle cars”. Taking into account the not monitored fate of “collision partners”, any car’s risk profile should include accident frequency and active unsafety as well as risk and crash test figures. Furthermore it must be noticed that specific car model risk statistics vary considerably over time and place. For example, the Volvo 240 or Mercedes 200

series perform less well in Australian risk ratings than in the US ratings.
It is therefore disappointing that HLDI and the US Insurance Institute for Highway Safety completely ignore these hidden risk factors and wrongly proclaim vehicle size to be the best safety guarantee ("buy big").

Table 2 Accident risk within size classes.

Type	risk of death	accident frequency
Average	1.0	100
Mercedes S	0.9	160
Cadillac Fleetwood	1.0	87
BMW 520	1.0	157
VOLVO 240	0.5 - 0.8	91
VOLVO 740	0.7	88
SAAB 9000	0.5	135
SAAB 900 4D	0.6	143
SAAB 900 2D	1.9	178
Porche 944	2.2	very high
Nissan 300 ZX	4.0	very high
Corvette	4.7	very high
VW Jetta	1.1	93
VW Golf	1.5	130
Golf GTI	1.5	164
Mazda 323	1.9	100

Source: HLDI statistics 1985 - 1989 (USA)

Trends in vehicle performance, market segments and car culture

On the basis of the correlations described above, a review of recent developments can help to indicate the necessary remedies. After a century of development, the car has been perfected technologically, with enormous improvements in user friendliness, comfort, handling, safety, performance, costs and emissions. In every respect, the car is big business and in many industrialised countries it accounts for over 10% of GNP. The dominant impact of this industrial product on our streets, the economy, activity patterns, our culture and emotions cannot be explained in terms of economic and demographic factors alone. A study of the factors determining car ownership, car use and driving habits [6] shows that "intrinsic" (affective) motives, connected with life style, satisfaction of emotional needs and cultural trends, have a major influence on motorists' behaviour and, consequently, on vehicle design and road safety.

Viewing the subject from a psychological angle, Sachs and Diekstra [7] show how the car fits in perfectly with the **factors determining behaviour**: the need for security and a territory; auto-regulation; anthropomorphisation; the need for physical power, heroism and social superiority (chivalrous competition); the desire to be different and project an identity; and the need to experience risks (neuronic stimulation). Car design and the irrational aspects of the car system cannot be properly understood without taking these unconscious motives into account. The usual concepts of status, freedom and privacy do not provide an adequate explanation. Being aware of these motives, one can notice how they work out in our culture and in political decisions that relate to cars, fuel prices or the car industry. Indeed, no other industrial product offers so much satisfaction for so many desires.

In recent decades, almost unnoticed [8], it has become customary for each new car model to be faster, more powerful, larger and heavier than the last model it in its own range. As a rule, cars are distinguished by their exact place in a hierarchy that is strictly dictated by dimensions, engine capacity, power, performance and image profile. The technological, psychological and economic developments of the car market are expressed in various forms of *upgrading*, which are part of the car culture and our spending patterns, and which counteract fuel efficiency:

A. *All cars are getting larger and heavier*.
Every model change since WW II proves that there is a law of continuous upgrading, due to the competition between car manufacturers, designing towards offering more than the current models or competitors in class. The interior space and the weight of the average European and Japanese car in each model range is now at the same level as that of the range above in the 1970s. The VW Golf Diesel body weight increased from 830 kg (model 1) to 1130 kg (model 4). The new Mazda 626, BMW 5 series and Mercedes S are the first exemptions, offering more interior space and performance with less size or weight than their predecessors.

B. *All cars are getting faster*.
Current small cars have the same performance as medium-range models 25 years ago, while medium-range models have the same performance as sports cars 25 years ago, and sports cars have the same performance as racing cars 25 years ago.
The proportion of affordable cars with a top speed of over 200 km/hour is soaring, thanks to turbos, four-valve cylinders, more swept volume and power output and low air resistance. It is not so much the upgrading in the top range that is striking, but that in the bottom and medium ranges. The average European family car now has a higher performance rating than the renown Mini Cooper S or the SAAB 850 GT, with which Eric Carlsson won the toughest rallies in the 1960s.

C. *The number of models and variants is steadily increasing*, as is the use of accessories that increase fuel consumption, such as air conditioning, tuning sets, and wide tyres. Uneconomical models such as Jeep-type vehicles, Pick-ups and MPVs are increasing their share of the market. Turbo-DI diesels offer petrol-level performance, and low powered variants (2CV, R4) have disappeared anyway. The number of engine variants (in cm3 and kW) and performances levels for each model range have dramatically increased. The result is a dynamic and more enticing range of models, with (upward only) variations in power, comfort and accessories to suit every taste. Publicity is generated by means of a massive multimedia campaign, with the trend being set by car magazine journalists, who, in their professional capacity, come into contact almost exclusively with the fastest cars.

D. *Motorists are buying ever larger, faster and more expensive cars.*
The sale of large cars and model variants with a high power rating and fuel consumption is of great commercial value: more is earned from these cars than from smaller or simpler versions of the same model. For instance, the basic VW Golf or Mercedes E or S is about half the price of the 1996 top versions.
For many motorists, each car they buy is larger and faster than the last.

Effects of upgradings

A comparison between European car models today and those of 10, 20 or 30 years ago in terms of power ratings, fuel consumption and performance shows that nearly all the progress in engine technology and efficiency has led almost exclusively to an increase in top speed and acceleration. From the standpoint of global warming, energy conservation and road safety, these trends are all in the wrong direction. The upgrading of the vehicle fleet has ensured that in most OECD countries the average fuel consumption of new (petrol-engined) cars has ceased to decline, after falling continuously since the first oil crisis. As a result of engine and materials technology and of lower air resistance, the performance of new car models will steadily increase, and at the same time they will become slightly more economical at constant speeds (by an estimated 1% per year) but not in practice.

The Kyoto CO_2 reduction targets and the energy conservation targets of most OECD countries will nevertheless not be achieved, if these trends are to sustain. Forecasts of transport CO_2-emissions in OECD and ECMT countries tend to show large increases rather than reductions or a standstill [9]. In a word, sustainable development remains unachievable within current "laissez-faire" approaches that do not address upgrading and performance.

As far as road safety and driving habits are concerned, the future looks even less rosy. Add-on (passive and active) safety features increase weight and offset part of the efficiency gains. Road network speed levels and driving dynamics have risen sharply in just a few decades. Speed limits in the Netherlands are exceeded during a third of the total mileage driven and the problem of overall and effective enforcement seems insoluble on the basis of current priorities. Attempts to improve driving habits by the “soft” means of information, education and public campaigns will remain virtually ineffective as long as performance continues to provide the wrong behavioral “stimulus configuration”. Assuming that the intrinsic and affective motives [Diekstra], or the quality of the infrastructure, cannot be influenced in the short term, a reduction in the potential speed of vehicles is an absolute prerequisite for achieving speed reductions. Thus, since driver self-control is becoming increasingly difficult to achieve voluntarily, one must think of *"vehicle self-control"* [10].

Limitation of speed, power and performance

Significant reductions in fuel consumption and CO_2 emissions per vehicle require not only best available technology but also the limitation of the top speed and - even more - the limitation of acceleration capacity by means of reducing power output and power-to-weight ratios. These ratios need to be reduced by at least 60% in every vehicle class to enable CO_2 emissions to be halved in the medium term despite a moderate growth in car use. In addition, weight reduction will remain necessary to compensate for the effects of the growth in car use. This would require a structural shift in the market so that the share of compact cars increases at the expense of cars weighing over 1,000 kg. The use of large capacity engines of over 2,000 cc or 100 kW would not be appropriate any more.
Specific power ratings would have to fall gradually to under 3 kW/100 kg.
Reducing absolute speed in all traffic conditions and collisions and reducing the frequency of overtaking behaviour will reduce both accident frequencies and fatalities dramatically!
Technologically, engine and performance downsizing is not a problem. The motor industry is quite capable of designing vehicles which meet modern safety and comfort requirements while being extremely economical in terms of fuel consumption (3 litres/100 km). On the basis of the performance level of popular diesel-powered cars from around 1980, such as the VW Golf and Mercedes 200D, the average fuel consumption can be halved if - using the best technology available - driving habits improve and the average vehicle weight declines.

> *The semi-sustainable European medium-range (Golf class) petrol-fuelled car in the year 2000 geared to a low fuel consumption, could have following characteristics:*
> *length: 4 metres; 4/5 seats; weight: <800 kg; engine capacity <700 cc; variable valve timing and/or compressor for high torque at low rpm; fully electronic engine management and intelligent transmission; top speed: <140 km/hour; 0-100 km/hour >20 seconds; 3 l/100 km fuel consumption. A fuel consumption computer (“economy-meter”or "black box") will optimise driving habits and save an extra 5% fuel.*

Policy consequences

How can current trends be reversed, given that fierce competition, low oil prices and the dominant car culture force manufacturers to participate in the race to constantly upgrade car models? What role can governments play in rolling back current upgrading and in downsizing power and speed? How can car manufacturers and retailers be brought to develop and sell fuel-efficient/low-powered cars that they do not believe to be profitable under current market conditions? And how can consumers be brought to purchase cars which they feel do not meet their basic needs as far as power, performance and image are concerned? One thing is for sure: those cars will not sell on the basis of current market preferences.

The first political statement in this direction was made by the European Conference of Ministers of Transport (ECMT). In their resolution of 21 November 1991, they came out unanimously in favour of limiting power and performance ratings for all categories of vehicles in the interest of road safety, environmental protection and energy conservation. The ECMT's call is also directed at the OECD, ECE and EU. More recently, in its communication on "A Community strategy to reduce CO_2 emissions from passenger cars and improve fuel economy", the European Commision finally acknowledged the role of upgrading and the need for reducing power and weight. The Commission under-lines the need to encourage fuel effiency through fiscal incentives, but unfortunataly it fails to identify engine downsizing and in-car feedback instruments as a "no regret" approach.

The question therefore needs to be addressed: what single or combined measures should be taken to achieve the "downgrading" of market trends and the downsizing of power and performance? Four different but related approaches can be distinguished:

A) social-psychological instruments, such as communication and education;
B) fiscal and economic incentives;
C) covenants or voluntary agreements with manufacturers;
D) (international) regulations, directives and standards.

A brief survey of these different instruments suggests that instrument A) cannot be considered effective, given current market preferences and "auto-cultural" values. The measures under B) and C) are favoured as an alternative to D) and can be highly effective once industry supports a target or a deal. But this will not happen in the foreseeable future, given current market preferences and the low oil prices and the promise of abundant future supplies, at least in the medium term. Thus the regulatory approach seems inevitable if politicians have the courage to promote stricter fuel efficiency and road safety at the expense of the current emphasis on performance. However, even if this were to happen, we should not harbour any illusions about the resistance which limiting the power-to-weight ratios or performance of cars will provoke. The "car-industrial-cultural complex" is likely to prevent any such approach from being embodied in directives until serious oil crises arrive. It must be concluded that it is the car industry that holds the key to any effective implementation of downgrading, be it voluntary or regulatory. In view of Kyoto and the long way to go, the first steps should now be taken by the OECD and EU member countries towards a comprehensive set of measures, starting with "no regret" measures and shifting to more unpopular and painful ones, as set out below:

A. Tax measures should be introduced to encourage purchase and ownership of compact and economical cars and discourage purchase and ownership of powerful, heavy and uneconomical cars. Such measures are currently being prepared in the Netherlands.

B. CO_2 emission standards and fuel consumption standards should be formulated for relevant vehicle size classes, and regularly tightened up. CO_2 standards need to prevent market reactance to upgrading, so fleet-average efficiency standards need to be incorporated as well. Standards can be set voluntarily or by EU directives.

C. Econometers, board computers and cruise control devices should be fitted as a standard in-car instrument that supports drivers in safe and fuel-efficient driving.

D. Speed limits should be enforced continuously and effectively so as to reduce real vehicle speeds and to improve driver's awareness of speed and fuel consumption. Current speed limits should be lowered to the levels where total costs/benefits to society are optimal: 90 or 100 km/hour on highways (LDV only; HDV: 80 km/h).

E. Speed limiters should be fitted not only to goods vehicles and buses but also to motorcycles, private cars and delivery vans, as a transitional measure towards the limitation of power ratings in all vehicles.

F. Power-to-weight ratios and the performance of passenger cars, motorcycles and, to a lesser extent, goods vehicles and buses should be limited within a tiered stepping-up time table for 2000, 2005, etc.

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