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AIR AND TRANSPORT INDICATORS IN NEW ZEALAND

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ABSTRACT

Transport, in all its forms, has a significant impact on the environment – particularly air quality. We often hear statements such as "*…vehicle emissions account for 70% of the world's air pollution…*". In many places this is true. Perhaps in some places its even worse, and others not so bad. But how do we know this? How do we assess and evaluate the effects of traffic emissions on air quality? And even more important, how do we judge the benefits or otherwise of trends, policies and legislative interventions?

We need a range of tools, some of which can be very complex and difficult to understand. The use of indicators in this application can be helpful – but what indicators do we use and how do we assess the relationships between them?

The Ministry for the Environment has developed a wide range of environmental indicators, and recently examined a specific series relating to transport effects on air quality. These include typical transport factors, such as vehicle numbers, and fleet mix, as well as typical air quality indicators such as ambient concentrations of key pollutants. The paper discuss interactions between these indicators using the *Driving Force, Pressure, State, Exposure, Effect, Action* (DPSEEA) model and examines how such indicators can be used to inform policy decisions and to improve transport management.

1 INTRODUCTION

Many urban areas in New Zealand experience elevated ambient air pollution from time to time. Elevated pollution levels in Auckland are largely caused by vehicle emissions, particularly around congested roads and intersections. Vehicle emissions are also responsible for the brown haze sometimes seen in the sky above the city. In contrast, high air pollution levels in Christchurch occur when smoke from home heating fires is trapped under inversion layers during calm, cold conditions in winter.

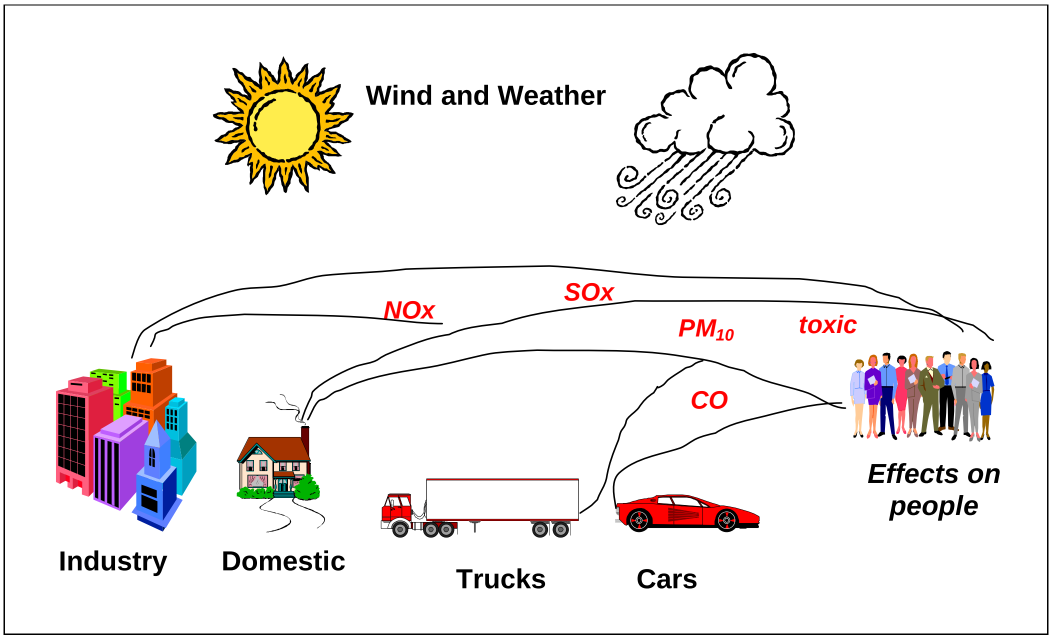
Vehicle emissions also contribute the largest proportion of New Zealand's carbon dioxide to the global problem of climate change.

While most forms of transport emit air pollutants in some form, the largest source is private motor vehicles (Wright, 1997; Wright & Kuschel, 1998). In terms of kilometres travelled (and hence total volume of pollution discharged), the private motor vehicle outweighs all other parts of the transport sector put together.

To understand how vehicle emissions affect air quality and determine how to reduce emissions to improve it, we need good information about the factors influencing the creation and impact of vehicle emissions. These factors can be used as "indicators" of the current state of transport and the air environment. Such indicators have been selected through the Ministry for the Environment's Environmental Performance Indicators Programme.

Indicators can be used to evaluate the effectiveness of policies and to gauge the significance of data, especially if the data can be compared to a target, objective or an environmental bottom line. In short, indicators are information tools. They summarise data on complex environmental issues to indicate the overall status and trends in those issues. They can be used to assess national and local performance and to signal key issues requiring policy interventions and other actions. In relation to air quality indicators, much of the focus of this approach is on protecting human health (Figure 1).

Figure 1. How pollution sources combine to affect people



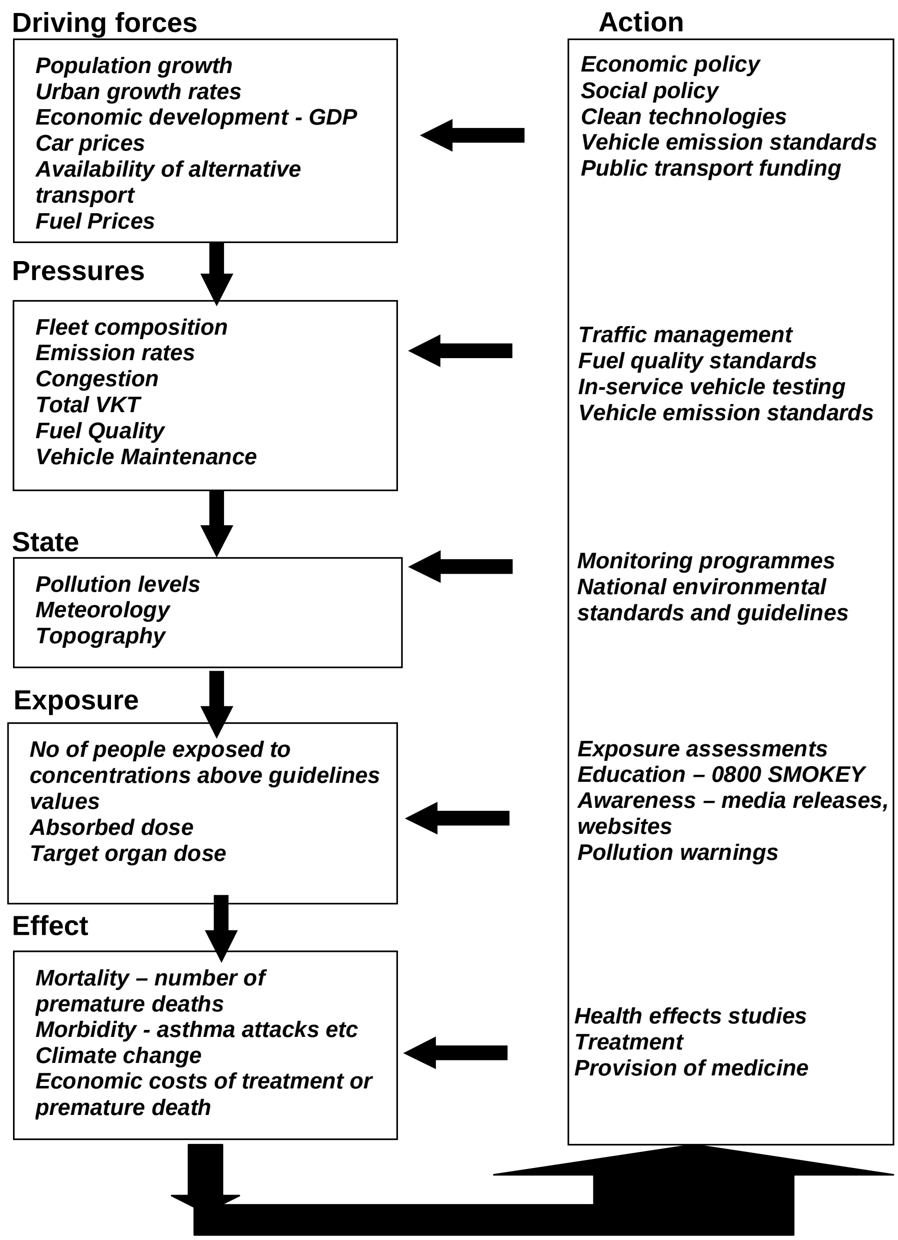
This paper uses selected indicators to assess the trends in factors influencing transport and air quality and explores the relationships between the various indicators. Like many environmental issues, however, the relationships are complex and many different factors influence emissions and the resulting concentration of a particular pollutant in an "airshed". In many cases the cause and effect relationships identified are tentative and require further analysis.

The paper attempts to summarise indicator data and trends on a national scale. However, data coverage is often limited and consequently some assumptions have been made when comparing national data with localised data. For instance, there is only a handful of permanent air quality monitoring sites located next to busy roads in New Zealand and hence the data are site specific. Extrapolating the data to provide a national picture is problematic and can only provide a rough indication of the relationships.

2 APPROACH

To examine relationships between air quality and transport the *Driving Force, Pressure, State, Exposure, Effect, Action* (DPSEEA) model (Figure 2) has been chosen. The DPSEEA framework enables better analysis of the human health risks of environmental conditions, and more clearly represents the ‘cause-effect’ relationships between human activities, environmental change and human health (Corvalan et al., 1996).

Figure 2. The DPSEEA framework used to define environmental health indicators for transport effects on air quality (Modified from Corvalan et al., 1996 and Kjellstrom, 1998).



The DPSEEA model includes: *Driving Forces* that influence people’s decisions about vehicle use and number. These in turn influence the *Pressures* – use of vehicles, types of vehicles and other factors affecting emissions from vehicles. Pressures then affect the ‘state of the environment’ which is divided into the environmental quality (*State* – concentrations of pollutants in the air), the *Exposures* (amount of pollution to which humans as exposed) and the *Effects* (actual health effects experienced by humans or the environment). Finally, *Actions* describe what is being done to address or examine the preceding factors.

The DPSEEA framework has retained the basic elements of the Organisation for Economic Cooperation and Development (OECD) Pressure-State-Response model, but it is more advanced in that it facilitates a more intuitive understanding of the links between steps in a causal 'chain' and the potential actions to break the chain. For a number of driving forces several different health effects may occur and these effects may be associated with several different exposures. Thus, the framework takes the shape of an inter-linking 'web' rather than a straight 'chain' for certain environmental health problems.

Discussion is provided in each section, including how the indicators might influence emissions from vehicles and air quality, and the availability of these data. The report focuses on describing how the indicator is changing over time, the factors influencing the indicator and whether it may change in the future based on particular actions.

3 INDICATORS

A large number of transport and air indicators have been developed through the Ministry for the Environment's Environmental Reporting Programme. A selection of those chosen, plus a few additional indicators are discussed below. The Ministry is currently completing the more detailed technical report from which these indicators are sourced and is also in the process of completing a *Guide to Monitoring and Data Management for the Environmental Indicators for Transport* and supporting technical information. Information will be posted on the Ministry's Environmental Reporting website www.environment.govt.nz as it becomes available.

3.1 Driving forces

The key driver of vehicle emissions growth is the growth in population and hence vehicle use. Percentage rates of growths for all New Zealand's main centres are shown in Figure 3.

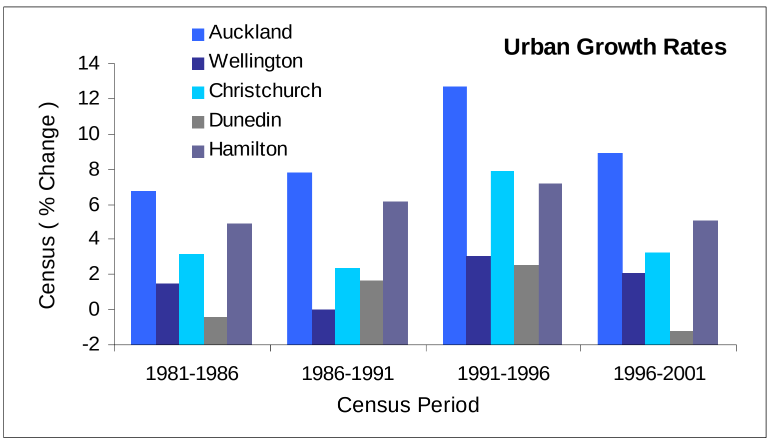


Figure 3. Growth rates for NZ main centres since 1980.

There are may other key driving forces not detailed here, including gross national product, fuel price and other economic indicators. A key indicator is the price of a new vehicle. As shown in Figure 4, this rose during the early 1990's but fell again in the latter 1990's making vehicle purchase more attractive.

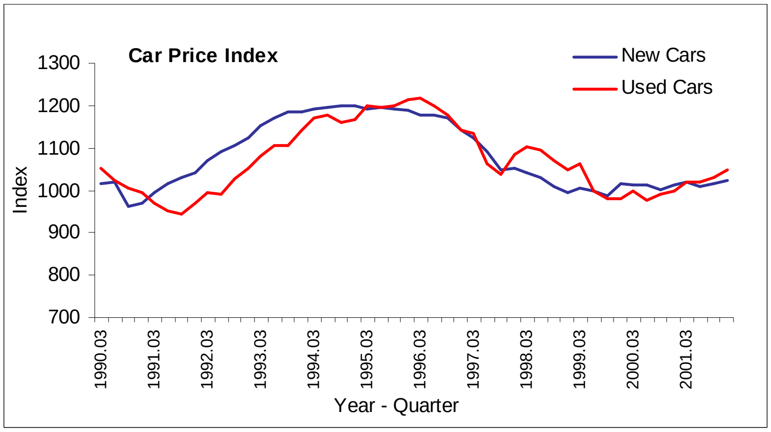


Figure 4.
NZ car price index since 1990.

3.2 Pressures

The pressures on vehicle emissions relate to factors such as how many kilometres are driven by the vehicle fleet (Figure 5), the fuel composition (Figure 6) and vehicle fleet composition (Figure 7).

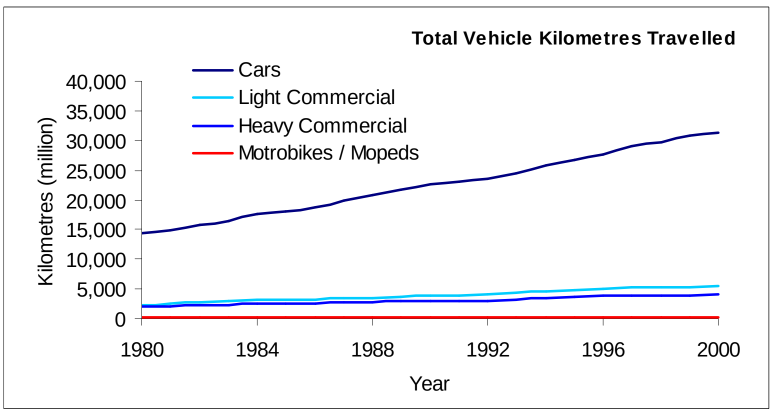


Figure 5.
Total vehicle kilometres travelled since 1980.

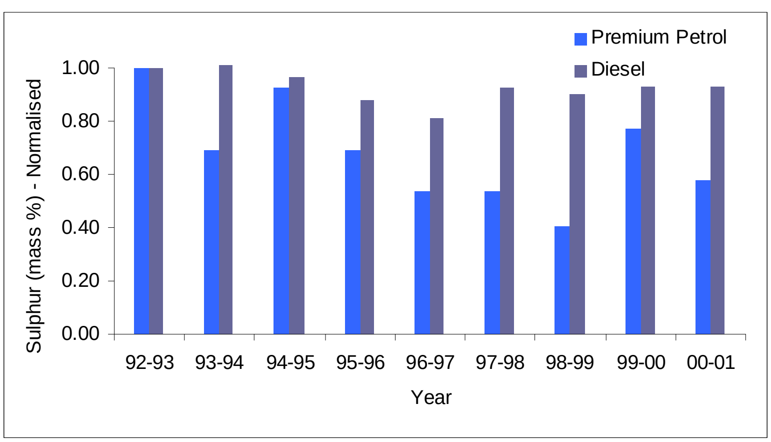


Figure 6. Sulphur content of NZ fuels since 1992.

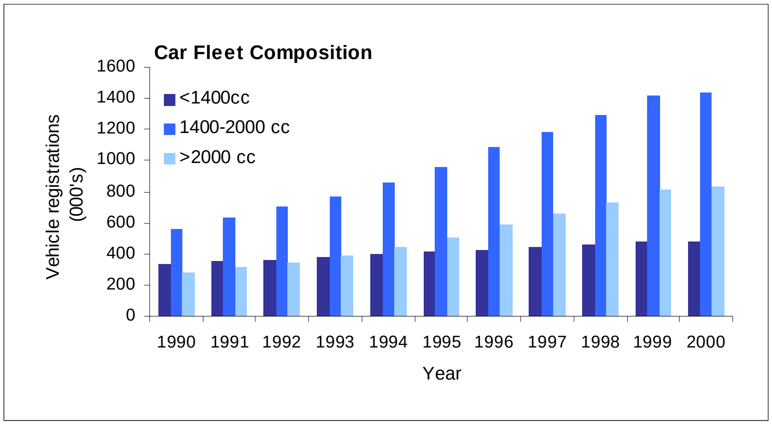


Figure 7. Vehicle fleet composition by size since 1990.

Sulphur in fuels (Figure 6) influences sulphur gas emissions from vehicles. These in turn can form small sulphate particles in the atmosphere contributing to elevated particle concentrations that cause adverse health effects as discussed in section 3.5.1. Sulphur can also reduce the effectiveness of emissions control equipment.

In the pressures category there are two indicators that are required, but are currently difficult to obtain in New Zealand – congestion and fleet averaged emissions. Both are essential requirements for air quality analysis, as both can substantially affect fleet emissions.

3.2.1 Congestion

There is currently no satisfactory indicator for congestion, although this is being addressed with some priority. Vehicles in congested flow can have significantly higher air pollution emissions per vehicle kilometre travelled (vkt) or per litre fuel used. Trials are currently being conducted on 'travel-time' criteria that should produce an indicator, although the sampling required to assess congestion over an entire urban area will be large. New techniques are being sought, one of which might comprise fleet tracking systems (e.g. by GPS).

3.2.2 Fleet emissions

The emissions from individual vehicles have been identified through models such as the Vehicle Fleet Emissions Model (VFEM) produced by the Ministry of Transport. However for some purposes it is necessary to know the fleet averaged emissions which cannot be explicitly identified from VFEM unless an exact profile of the fleet is available – which it often is not. This question has recently been addressed through an on-road remote sensing study which gives some key indicators of the actual emissions of a series of vehicles passing the sampling site (Kuschel et al., 2003). This has identified a number of features of the emissions. Some expected – such as older vehicles generally produce higher emissions, but some only previously assumed – such as a small portion of the fleet is often responsible for the bulk of the emissions. A full report is being prepared (Fisher et al., 2003). Actions to determine fleet emissions are discussed further in section 3.3.

3.3 State

Information is available on the state of air quality through the Ministry's Air Indicators, and from ambient monitoring conducted by regional councils throughout NZ.

These cover a reasonable range of the typical air pollutants of concern – particularly nitrogen dioxide, carbon monoxide, sulphur dioxide, particles (as TSP, PM_{10} and $PM_{2.5}$), ozone and hydrocarbons.

Two examples are shown in Figures 8 and 9. More information is available either on the Ministry for the Environment's Environmental Reporting website (www.environment.govt.nz) or through the web sites of various councils. Figure 9 shows how annual average NO_2 concentrations may be increasing over time in Auckland.

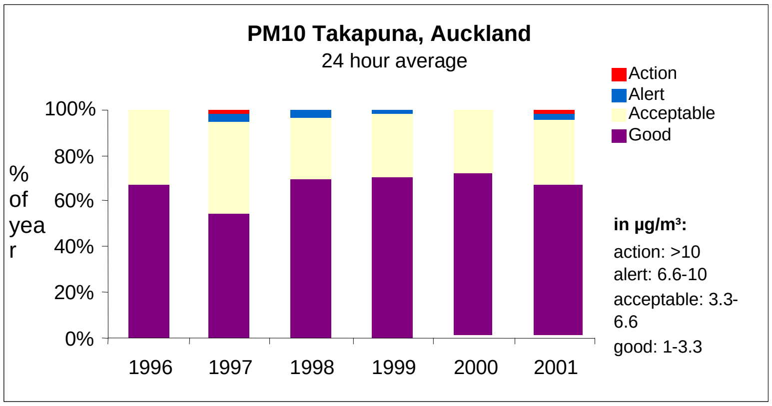


Figure 8. Environmental performance indicators. Example of PM_{10} from Auckland.

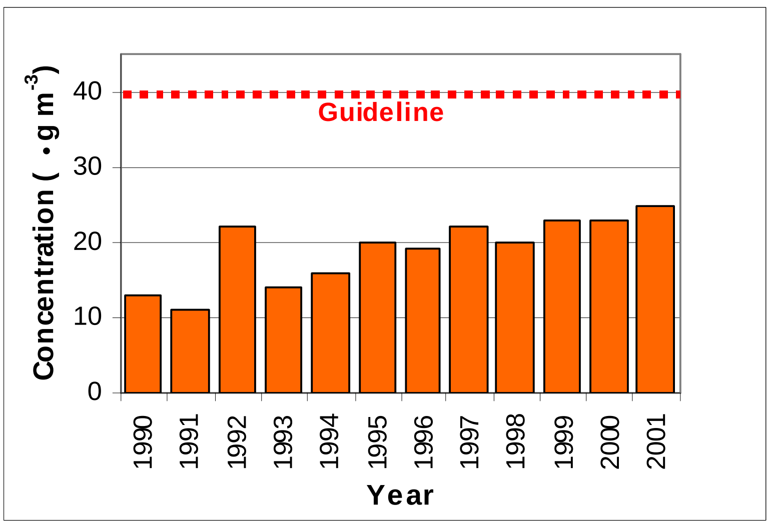


Figure 9. Growth in annual average nitrogen dioxide in Auckland

3.4 Exposure

Once the information about state indicators is collected, it is possible to determine the exposure experienced by the environment and people.

Exposures can be assessed in a number of ways. The first is to use data from monitoring sites and simply extrapolate this to areas of interest. Another is to use airshed modelling (with measurements as input) to give more detailed pictures of the area exposed to the contaminant (Figure 10). Another is to determine surrogate relationships with inventory information. For example, the total vkts in an area is a good indicator of peak concentrations of air contaminants from vehicle emissions (although weather and geographical factors are also important determinants of total exposure).

All of these techniques are used in order to assess exposures (e.g. Fisher et al., 2002). Further work is needed on some aspects, such as taking into account the activity patterns of people – who will generally spend time in different areas, and taking account of exposures inside homes and work places – which are not well accounted for with these methods.

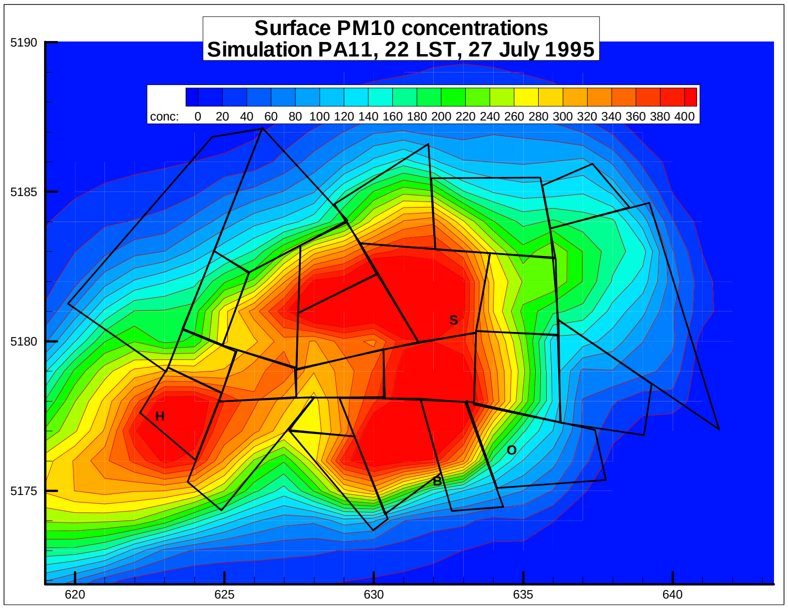


Figure 10. Modelled PM_{10} concentrations in Christchurch

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3.5 Effects

The next step in the DPSEEA process is to develop indicators for 'effects' of the air emissions by transport. This subject is embryonic and wide ranging. The major effect addressed so far has been the health effects of some of the contaminants – particularly PM10 – such as premature mortality and hospitalisations. However there are a range of other effects, including degradation of building surfaces, effects on plants, amenity effects (such as visibility degradation), and climate change effects (through CO_2 emissions). A full discussion of each of these is beyond the scope of this paper, and only a few summary results are presented.

3.5.1 Health effects

There are a number of possible health indicators of air pollution, such as the number of premature deaths and hospitalisation, and a full discussion is presented in a related paper (Scoggins & Fisher, 2003). However there are some key indicators. One of these, derived form the health effects assessments (Fisher et al., 2002), is an estimate of the costs due to vehicle related air pollution (Table 1).

Comparison of studies – health costs due to vehicle PM_{10}.

Study Source	*Cost per person per year ($NZ)*
MoT 2002 (Auckland specific)	$260
Canada 2001	$273
Switzerland 1998	$295

Table 1. Example of the effects of vehicle emissions.

Although a preliminary, and as yet un-published assessment, Table 1 shows that the approximate cost per person for transport related air pollution is on a par with what might be expected based on similar assessments for Europe and Canada – at around NZ$260 per annum.

3.5.2 Visibility

Another example of an indicator of effects, is an assessment of visibility degradation in Auckland. It is well established through regional council studies and publicity that vehicle emissions are the major source of much of Auckland's air pollution. Figure 11 shows a panorama of the city's 'brown cloud', which is most likely NOx and particles.

Figure 11. Auckland city 'brown cloud' in July 2002.

A series of digital camera images have been collected to assess the occurrence of Auckland's brown cloud. For the 2002 year, it was found that the daily visual range and/or appearance fell into the 'action' or 'alert' categories for 8% of the time. Summary results in Table 2 show that this was on 16 days per year. (Only days without significant rain or cloud could be included, which in this case was 273 out of 365).

Category	**Visual range +/or appearance**	**Results**
Excellent	70 km + and no 'off' colour	25
Good	20-70 km and no 'off' colour	184
Acceptable	20-70 km and discernable 'off' colour	48
Alert	<20 km and discernable 'off' colour	3
Action	<8 km and/or distinct 'off' colour	13

Table 2. Visibility indicator assessment-Auckland 2002. **Days of category (only non-rain days included).**

Visibility is a relatively good indicator of transport emissions – at least in Auckland. It is very noticeable by the public and accepted as an environmental issue worthy of actions leading to its improvement.

3.5.3 Climate Change

The effect of transport emissions on climate is a subject that warrants special attention, and is not covered here. However, any discussion on the air emissions effects of transport cannot exclude it. Increasing temperatures may affect air quality in terms of potential for formation of contaminants such as ozone and it may reduce emissions from sources such as home heating, as temperatures get warmer.

Figure 12 shows, in a highly simplified form, the global warming scenarios that are becoming widely accepted. NZ has signed up to the Kyoto Greenhouse reduction agreements. A number of agencies are now actively seeking ways to reduce emissions of greenhouse gases from the transport sector.

Mitigation of greenhouse emissions – especially CO_2 – will become a growing feature of transport related operational and design decisions.

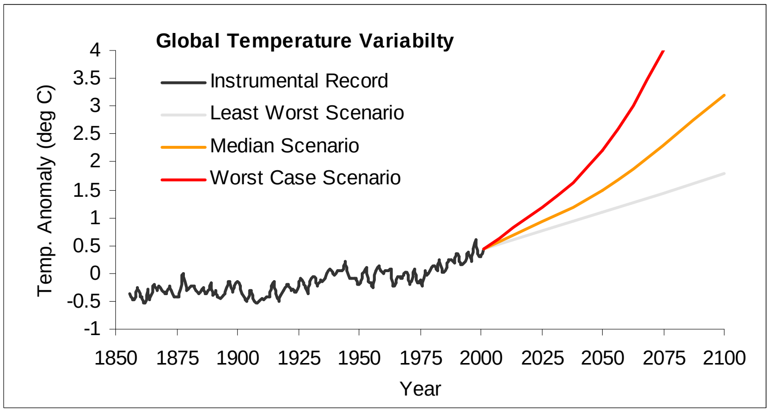

Figure 12. Global warming scenarios from the IPCC.

3.6 Actions

As listed in Figure 2, a range of actions can be implemented to reduce vehicle emissions and their impacts on air quality. Analysing these actions is a significant task and one that road controlling authorities, councils and the Ministry of Transport put considerable resources into. This section will briefly summarise actions currently planned or underway to reduce vehicle emissions. It will focus mainly on central government initiatives.

Actions do not lend themselves to being reported over a time series. They tend to represent a decision made at a point in time and are not usually presented in graphical form. Once implemented, however, their impacts can be evaluated by tracking changes in the pressure and state indicators.

3.6.1 Traffic management and transport planning

Road controlling authorities including local councils and Transit in collaboration with regional councils are responsible for traffic management, transport planning and landuse planning. These agencies can influence vehicle emissions by considering the impacts of traffic management and planning decisions on air quality.

Because vehicle emissions significantly increase from congested traffic, measures aimed at reducing congestion can improve air quality as well as travel times. However, care is required to ensure that the congested conditions do not simply move to another area of the transport network, or that short-term improvements are lost in the long term as vehicle usage increases.

The Ministry of Transport has developed tools to assist road controlling authorities to evaluate traffic management options. These include the Vehicle Fleet Emissions

Model (Ministry of Transport, 1998a) and case studies demonstrating the application of Environmental Capacity Analysis (Ministry of Transport, 1998b). Uptake and use of these tools has been variable and further guidance is being prepared on how the model can be used assess transport decisions, develop emissions inventories and create data for dispersion modelling.

Increasingly, air quality issues are being taken into account in decisions on landuse planning, roading and traffic management. However, there remains some confusion around whether and how the impacts on air quality should be considered. Assessment of the potential impacts of transport management decisions on air quality, along with all the other factors that need to be considered, will ensure a more informed process where all the environmental and health benefits and costs are taken into account.

Air quality improvements resulting from traffic management and planning can be tracked through the pressure and state indicators.

3.6.2 Fuel quality standards and cleaner technologies

Fuel quality directly influences emissions from vehicles and the effectiveness of emissions control equipment, particularly equipment on modern vehicles designed with specific fuels in mind. If compatible fuel is not available, the introduction and use of cleaner vehicles may be delayed and consequently emissions will not be reduced as quickly as they could be.

The revised NZ Petroleum Products Specifications Regulations 2002 require a gradual reduction of several substances in diesel and petrol that are known to contribute to the formation of harmful emissions such as PM_{10} and benzene. These improvements, in conjunction with corresponding emissions standards (section 3.6.3), should enable and encourage the introduction of cleaner vehicles with effective emissions control equipment. The revised specifications are generally in line with Australia's, however, they are behind those in the US and Europe. Consequently, some newer models, especially diesel vehicles with particle traps that require virtually sulphur free diesel, may not be introduced as quickly as in other countries.

Figure 13 shows one prediction for the introduction and uptake of new vehicle technologies in the USA. Current projections are for a rapid adoption of cleaner emissions vehicles, but even by 2020 there may be a significant fraction still of conventional fossil fuelled combustion engines.

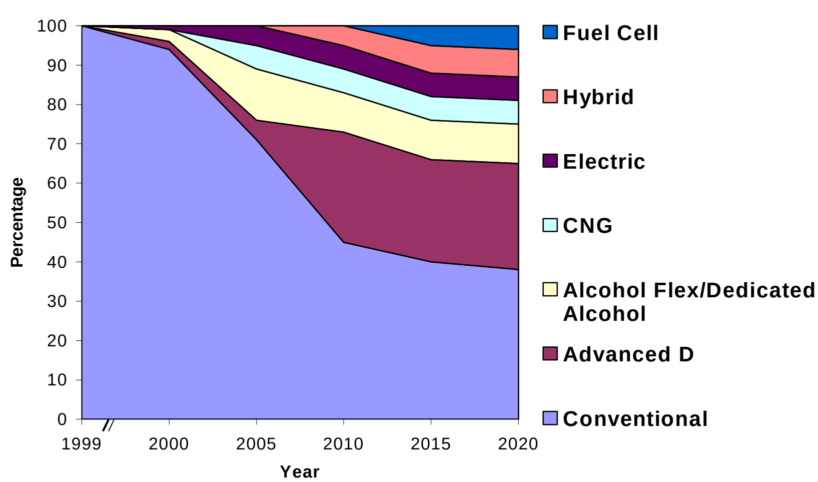

Figure 13. Vehicle technology trends (USA).

Some of the regional councils, who are responsible for regional bus services, encourage bus providers to purchase and use buses with newer technologies, such as the gas/electric hybrid buses introduced in Christchurch.

The Energy Efficiency and Conservation Authority has recently released the Draft Eco-Efficient Motor Vehicles Strategy (EECA, 2003). This aims to improve fuel economy and reduce carbon dioxide emissions from the transport sector in New Zealand. Measures to reduce CO_2 emissions from vehicles will generally (although not always) bring about reductions in emissions of local air pollution contaminants.

3.6.3 Vehicle emission standards

The Land Transport Rule: Vehicle Exhaust Emissions 2003 will require petrol and diesel vehicles (manufactured after 1990) entering New Zealand to be manufactured to an appropriate international exhaust emissions standard applicable in one of four jurisdictions United States, European Union, Japan and Australia, or be 'type approved' for sale in one of those jurisdictions. The rule will take effect from 1 January 2004, and the requirements phased in over the period from 1 January 2004 to 1 January 2007. The rule will not require evidence of on-going compliance with those standards.

This rule should ensure that new vehicles entering New Zealand meet up-to-date emissions standards and that used vehicles were manufactured to meet an emission standard. It will prevent vehicles that are not constructed to an emission standard from being imported into New Zealand. Potential further checks to ensure that used vehicles are still operating reasonably within the deterioration rate allowed by the standards, are being evaluated by the Ministry of Transport.

Although not exactly an emissions standard per se, the police also implement the "10 second smoke" rule in New Zealand. This rule states that vehicles emitting visible smoke for more than 10 seconds can be subject to an infringement notice and fine. Environment Bay of Plenty has a similar rule in their regional air quality management plan. These requirements aim to ensure that excessively smoky vehicles are repaired or removed from the road. Indicators of their effectiveness include the number of tickets issued and feedback from public education campaigns, such as the Auckland Regional Council's 0800 SMOKEY campaign.

3.6.4 In-service vehicle testing

The Ministry of Transport is developing options for an in-service vehicle emissions screening programme and it's implementation in New Zealand. Decisions on the proposed programme are due to be made shortly. Any programme is likely to be implemented through Land Transport Safety Act rules. The programme will aim to identify the worst polluters responsible for a disproportionately high contribution to ambient air pollution.

The success of emissions screening can be evaluated using the pressure and state indicators discussed earlier. Data on which to report these indicators can be obtained from a variety of sources such as the emission testing itself or on road emissions testing. On road testing was recently trialled in Auckland by the Auckland Regional Council. This involves setting up a road-side sensor (Figure 14) that can detect emissions properties of individual vehicles. During May 2003 some 40,000 vehicles were measured, giving a wealth of indicator information (Kuschel et al., 2003). One of the key results was that the effect of the 'gross emitters' was quantified – and they are significant contributors to air pollution.

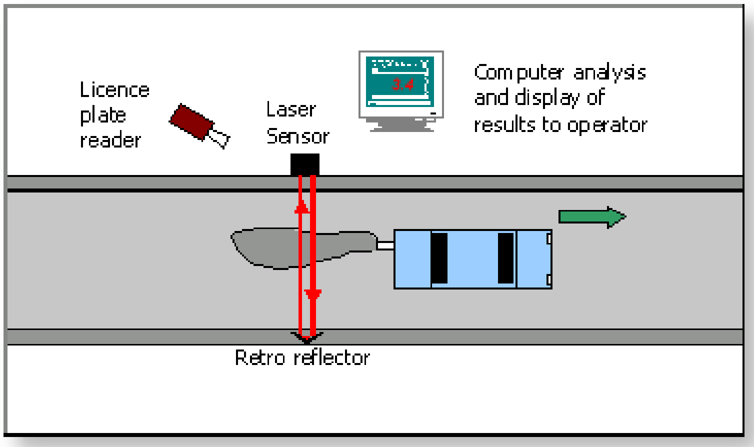

Figure 14. Remote sensing of vehicle emissions – Auckland 2003.

3.6.5 Public education, pollution warnings and raising awareness

Public education is useful for dispelling myths (such as the widely held view that removal of catalytic converters always improves vehicle performance – it can do, but only if the catalyst is not working properly and should be replaced anyway) and encourage behaviours that will either improve emissions from individual vehicles such as regular vehicle checks, tuning and maintenance, or encourage people to use less polluting modes of transport, such as cycling or walking. The impact of education programmes is often difficult to measure, however, pre and post campaign surveys can determine knowledge uptake whether people have acted upon the messages. Extrapolating this to environmental or air quality improvements, however, is very difficult.

Education is also an important part of implementing any new regulations or rules, such as those relating to in-service testing, particularly if increased costs are involved.

3.6.6 National environmental standards and guideline values

To drive air quality improvements, the Ministry for the Environment has prepared and recently revised, national *Ambient Air Quality Guidelines* (Ministry for the Environment, 2002). Guideline values for specific contaminants represent the minimum requirements that air quality should meet to protect peoples' health. They are typically used as targets to achieve through regional air quality plans and national policy decisions.

The Ministry for the Environment is currently developing national environmental standards for ambient air quality that take the form of formal regulation. These standards aim to drive further improvements and actions to reduce emissions, particularly where the standards are breached.

The impact of guideline values and standards (when promulgated) can be evaluated using the pressure and state indicators, and by determining whether additional actions have occurred because of their introduction. Caution is needed, however, when trying to link improvements back to national ambient requirements, as there are many other factors also influencing the indicators.

3.6.7 Monitoring programmes

Many regional councils operate comprehensive ambient monitoring programmes, consisting of a network of monitoring sites where key indicator contaminants such as CO, NO_2 and PM_{10} are monitored. The purpose of these sites can vary and may include: tracking trends in pollution levels over time, identifying pollution hotspot areas, and determining background pollution levels.

Monitoring programmes provide the data for the state indicators. They are crucial for evaluating the success of policies (through air indicators) and for feeding into exposure and health effects studies.

Several councils also have comprehensive transport monitoring programmes, although their scope and the type of data collected varies throughout the country. As part of their programme, Wellington Regional Council prepared an *Annual Report on the Regional Land Transport Strategy* (Kelly, 2002) covering a range of demographic, transport, economic, efficiency, affordability, environment, sustainability and safety indicators.

3.6.8 Health effects studies and exposure assessments

Health effects reviews and exposure studies are required to understand the potential costs of air pollution to New Zealand and the benefits of introducing various actions. They can also assist in setting standards and guideline vales as described above.

A three-year study into the exposure and health effects of air pollutants funded by the Health Research Council, Ministry of Transport and Ministry for the Environment commenced in 2002. This study will provide the most robust analysis of the health effects of air pollution and potential means to address them so far attempted in New Zealand (Scoggins & Fisher, 2003).

3.6.9 Treatment and provision of medicine

Very little is known about the costs of treatment or increased use of medication arising from the health effects caused by air pollution. The three-year study described in section 3.6.8 will go some way towards estimating such costs. However, this is an area of ongoing research. In general, control of emissions is seen as a more effective option for dealing with air pollution than putting money into the treatment of related illnesses.

4 CONCLUSIONS

This paper identifies a range of indicators that can be used to assess and manage the effects of vehicle emissions on people and the environment. Indicators are a important tools for making the connections between 'driving forces' –> 'pressures' –> 'state' –> 'exposures' –> 'effects' –> 'actions' which all have very complex components.

This paper does not cover the full analysis, or all of the indicators. Indeed, as discussed, there are still gaps such as a reliable congestion indicator. However, it does show the range of indicators currently developed, and some of the apparent trends. It also highlights the importance of determining appropriate indicators when developing policies. Without good indicators it is impossible to analyse the success or failure of the actions taken.

Indicators of transport emissions and air quality are just one tool. The need for information about the consequences of trends and policies is great – and the connections between the various components are very complex. Simplistic analyses are very tempting, but rarely lead to a satisfactory outcome. Transport indicators can at least help identify some of the important features and consequences of our transport decisions as a society, and point the way to where further more detailed analysis is required.

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