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▪ report

Smartgrowth - New Technology

Revision History

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Prepared by	Ian Bone		29 Mar 03
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2 Introduction

2.1 Purpose

Smartgrowth takes a long term (50 year) view of transport and land use development in the Bay of Plenty Region. Over such a lengthy period, factors underlying transport demand may undergo substantial change and accepted norms for forecasting may be called into question. There is time for the density and pattern of land development to influence private vehicle ownership and mode choice. Similarly there is the time for new developments in transport, communications and information technologies to become commercialised and to exert an influence.

The aim of this paper is to review trends and influences in new technology and how these may be factors in future planning of the region.

2.2 Transport Demand

2.2.1 Activities Driving Transport Demand

Transport is largely a derived demand. Most travel and transport is undertaken to serve activity that occurs at the origin and destination of the trip. These activities can be broadly grouped into trip purposes and any view of the future should consider how the future time commitments to various activities, and their spatial distribution, may change with new technological influences.

These activities include:

- residential - where and how people choose to live, residential densities, location relative to the workplace, shopping and education
- wholesale and retail industry organisation, and consumer preferences in methods and times for shopping
- location of schools and other educational establishments, methods of learning, catchments of the student population, distance learning versus attendance
- distribution of outlets for personal and official business – banking, postal services etc
- commercial offices location – central urban or decentralisation of workforce and functions to lower cost areas, regionally, nationally and internationally;
- industrial activities – structure of firms, location of major manufacturing, warehousing, storage and distribution, freight logistics;
- changes in the economic base and the employment shares between primary industry, manufacturing and service industry; effects of automation and information technology impacts on business employment ratios;
- social and recreational habits and preferences.

Transport on the one hand responds to these underlying influences and, on the other hand, acts either as a constraint or as a driver to change in the organisation and spatial pattern of activities and land use.

2.2.2 Passengers, Goods and Information

Transport planning tends to concentrate on the movement of people as, in present day western society, people movement is the predominant component of road traffic, accounting for roughly 85% of the traffic stream, with light commercial vehicles comprising 10% and heavy goods vehicles the remaining 5%of the traffic. Of course heavy goods vehicles have a greater influence than this percentage implies, being equivalent to between two and three cars in use of roadspace and congestion effect.

While people may have some alternatives to passenger cars - walking, cycling and public transport, there is no alternative for goods movement. Rail is not, and will never be, a substitute for road freight within urban areas, apart from some very limited shuttle movement between freight terminals. Freight movement is also an essential underpinning of the economy for both domestic consumption and export earnings. For a healthy and thriving economy, road freight movement needs to be effective, cost-efficient and reliable, while conforming to the goals of liveable communities and maintenance of environmental standards.

As well as the movement of people and goods, the movement of information is also a source of transport demand. The technical feasibility for telecommunications to substitute for travel has been expanding, but the reality has been less impressive. The dynamics of human interaction makes voice or even video contact less effective than a physical presence. While remote working on information-related tasks is now much easier, there are constraints to do with management overview and control, establishment of suitable remote working environments, and the social dynamics within organisations that limit the extent to which these opportunities have so far been taken up.

2.3 An Historical Perspective

While the future may hold changes wholly different from the past, a review of what has happened can be instructive when considering what may happen.

Private means of transport have always existed and pre-date public transport. Walking has always, and continues to be, the most basic form of private transport over short distances, and longer distances where no alternative is available.

Historically, and still today in some countries, animals were used for private transport either ridden or drawing various forms of carriage, cart or car. The bicycle provided a means of extending the mechanical advantage of human power, and still remains the most mechanically and energy efficient form of personal transport.

In the 19th century, the invention of the steam engine allowed the development of rail transport, which became the dominant mode for long distance passenger travel. Later, the street tram developed to serve urban passenger transport, both gradually displacing horse traffic. In New Zealand as in other countries, urban development followed the expansion of tram services in the main cities. Business and industry were still largely centralised, and that central focus for many New Zealand towns and cities was on a seaport. Long distance transport was largely by coastal scow, river transport and rail.

The invention of small internal combustion engines powered by petroleum fuel allowed the development of the motorcar and motorbike as we currently know them at the end of the 19th century, but initially costs were high and affordable only by a few. In the 1930s and 40s this changed with mass production of motor vehicles and from this point on, apart from a hiatus through WWII, the cost of owning and operating motor vehicles has reduced and car ownership has inexorably increased.

The increasing price competitiveness of the private car has steadily eroded the market for public transport, at the same time allowing easier access to the urban periphery and encouraging the low density suburban development so characteristic of post-war cities in North America and Australasia. In turn this has diluted the demand for transport along defined corridors of flow, further eroding the economics for public transport, particularly the relatively inflexible and high cost rail-based systems. In the post-war period, street tram services went into decline, and trackwork was removed to make way for pneumatic tyred cars and buses. Improvement of the national highway system, and the completion of a sealed network with gradually improving geometric standards, has undercut long distance passenger rail and again, in line with world trends, rural branch lines and long distance passenger services have gradually become unable to financially compete against road.

Suburban passenger rail services have survived in Wellington and Auckland, although regional services have been cut in recent years. Wellington's service had the benefit of some strong geographical concentration of passenger flow, large capital subsidies while the system was being developed, up until the privatisation of the rail system. In Auckland, a run-down system is now being revived in the face of severe urban congestion, high rates of population growth, and limited space for new road building. How successful this high cost venture will be remains to be seen.

Telecommunications have developed in parallel with mechanised transport, through semaphore, telegraph, and wireless communications. Broad band internet access, high capacity urban fibre-optic communications links, and distributed computing with high quality audio/visual interfaces all provide the opportunity for remote monitoring and control, for personal communications, remote working, document transfer all with some and transport substitution potential.

Thus, the present dominant position of powered private motorised transport has resulted first from scientific discovery, then technological exploitation and industrial production methods that have increased scale and lowered prices. Cheap and relatively fast urban transport made it possible to work in the city and live in a semi-rural environment, and encourage low density development of urban land within commuting time of the business centres. Increasing accessibility to private means of transport freed this development from siting along public transport corridors. In turn, this dispersed development pattern has weakened the viability of public passengers services, particularly those that rely on high levels of demand along confined corridors of flow.

2.4 Future Prospects for 2051

In 1901, the changes to urban form and means of transport that occurred by 1951 could scarcely have been guessed at. However, from 1951 to 2001, the technology of the private car has remained unchanged in its basic form, although much refined. A 50 year future in 1951 would have been predictable.

Looking forward from 2001 to 2051, will changes be as dramatic as the first half of the 20th century, or "more of the same" as in the second half ?

2.5 Emerging Technologies

[list the technologies that are emerging that could influence use of transport over a 50 year period]

3 Recent Trends

3.1 Profile of the NZ Vehicle Fleet

The stock of road vehicles represents a very large and widely distributed capital investment by the community in the transport system. Cars are the second largest individual item of consumer expenditure after house purchase. Nationally, there are over 2 million cars and half a million other vehicles in the vehicle fleet, with a combined market value of around 35 billion dollars. The average age of vehicles in the fleet is 10 to 12 years, and the average lifetime around 18 to 20years. This investment commitment and age profile indicate that any radical change in new vehicle technology will take many years to penetrate the market.

3.1.1 Age, Fuel Type and New/ex-Overseas

The New Zealand car fleet is old by international standards. While most cars are petrol fuelled, since the mid-1980s there has been a high level of used imported vehicles, mainly from Japan, a large proportion of which are diesel powered. These ex-overseas imports are generally 4 to 5 years old at importation, and the effect has been to produce a bulge in the number of 5 to 15 year old vehicles in the fleet (Figure 3.1).

Prior to the period of ex-overseas imports, almost all vehicles were imported new and the profile of the fleet was quite different (Figure 3.2). In fact, between 1978 and 2002 the mean age of vehicles in the car fleet increased, mainly due to the effect of these old used imports.

The profile of the light commercial vehicle fleet shows a similar, although less pronounced middle-age spread. What is more evident is a progressive move towards diesel fuelling in the light commercial fleet. This started with the used import market and, for a time, a large number of old Japanese diesel vehicles were imported at a time when the emissions control requirements for diesels in that country were relatively undemanding. More recently, the pattern has been more towards importing modern light diesel vehicles.

The heavy vehicle fleet has been almost exclusively diesel powered for some years. Again, the fleet is relatively old. Over the years there has been a polarisation in vehicle sizes from a relatively even spread over the bands of gross vehicle weight to a concentration in the higher and lower weight categories (see Figure 3.5). The bulge in smaller vehicles in the mid-age range is again a reflection of used imports in these weight groups.

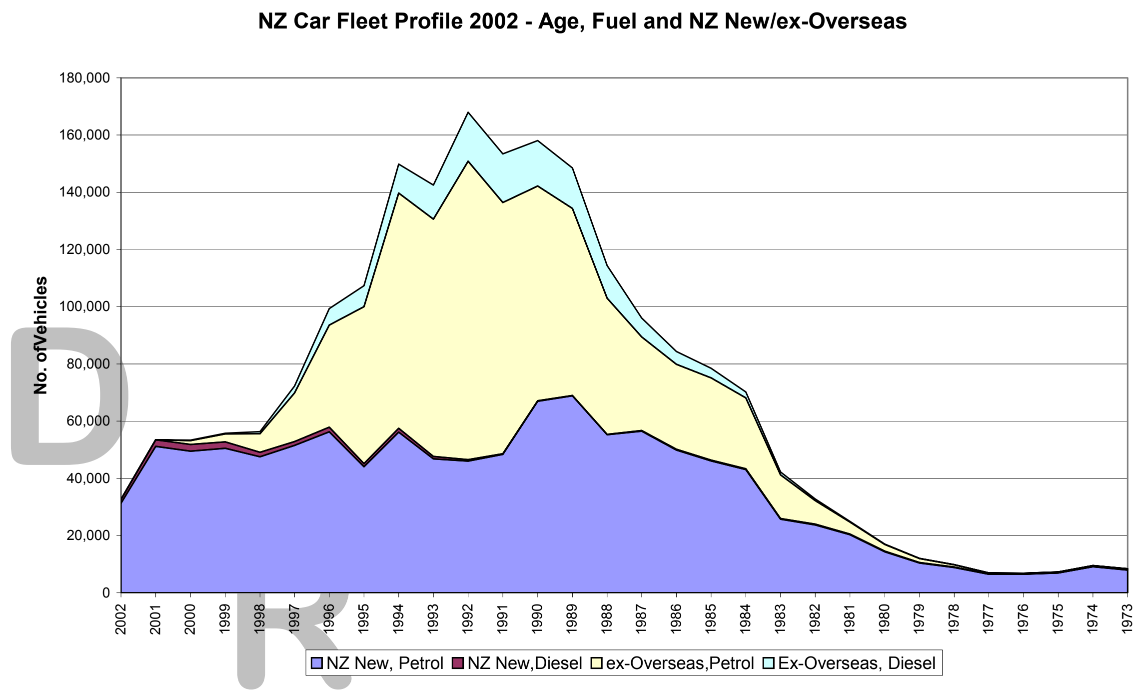


Figure 3.1 - NZ Car Fleet Profile, 2002

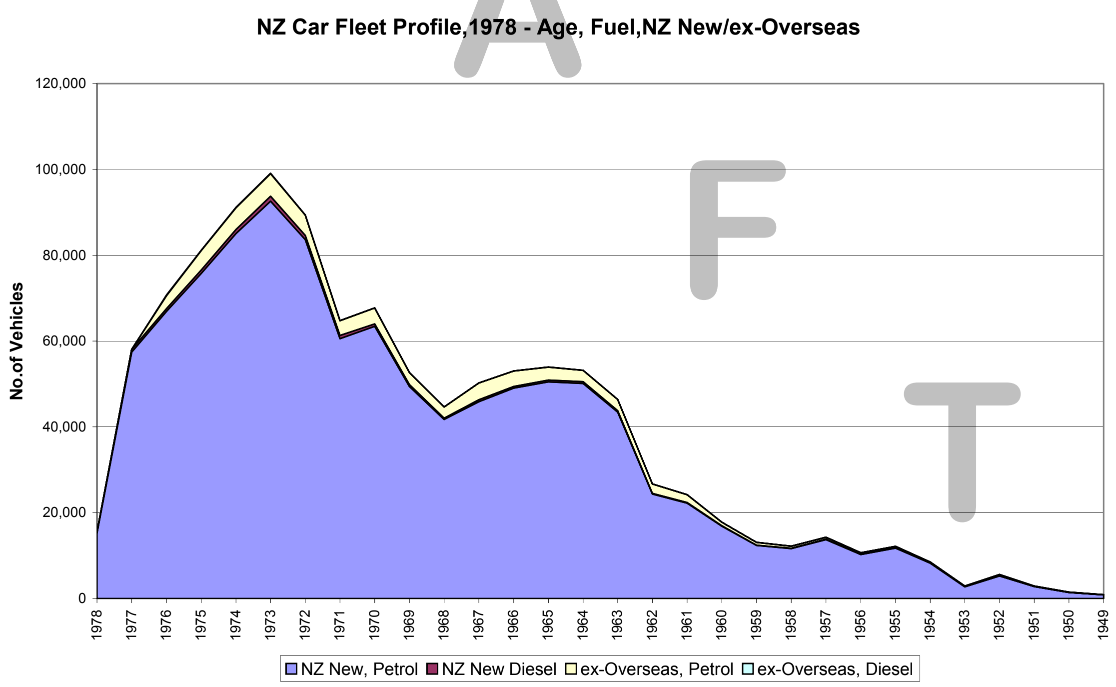


Figure 3.2 - NZ Car Fleet Profile, 1978

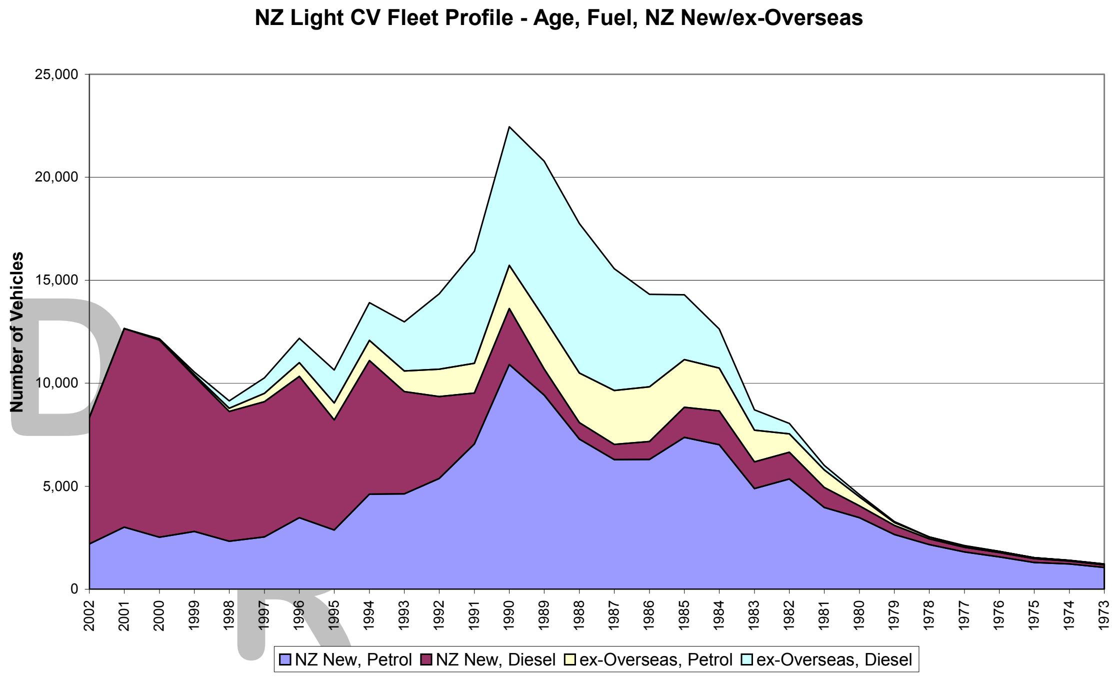


Figure 3.3 - NZ Light Commercial Vehicle Fleet Profile - Age, Fuel Type, NZNew /ex-Overseas

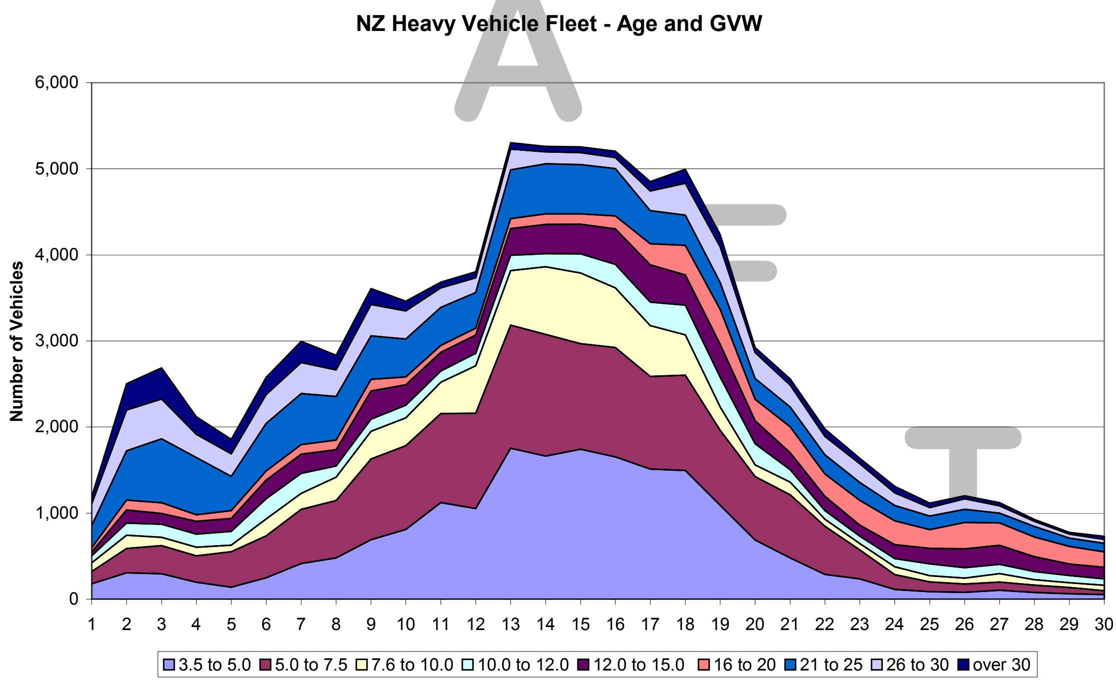


Figure 3.4 - NZ Heavy Truck Fleet - Age and GVW

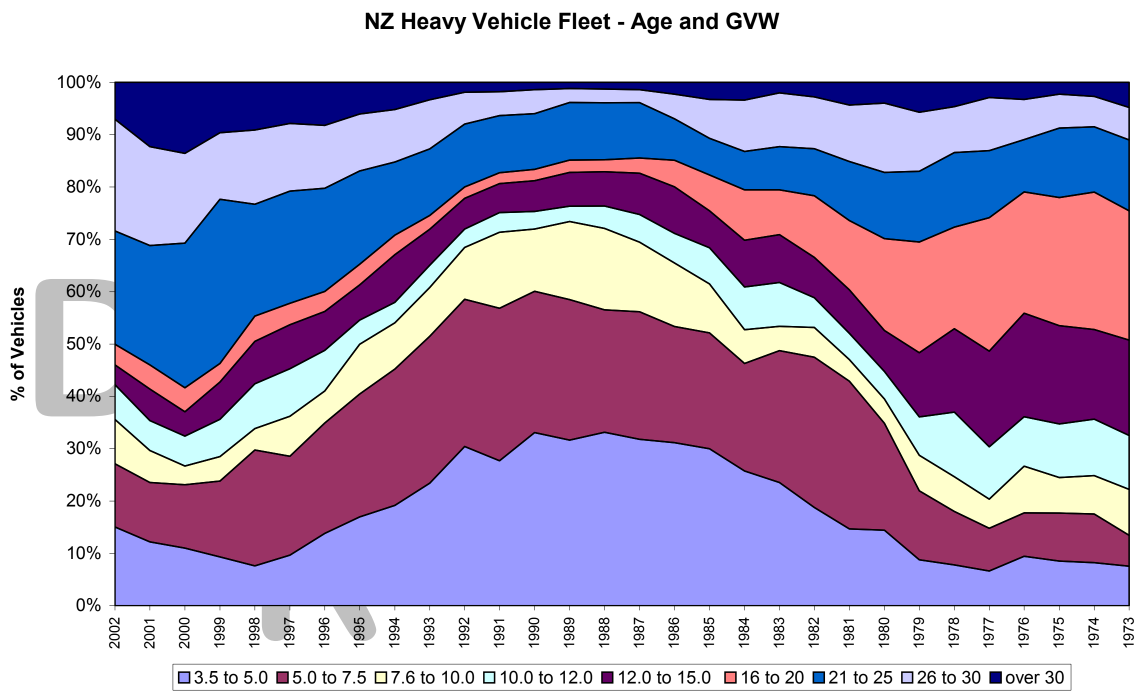


Figure 3.5 - NZ Heavy Vehicle Fleet - % Weight Group by Age

The trend to import used cars shows no sign of abating, although the proportion of older commercial vehicles now being imported has fallen (Figure 3.6).

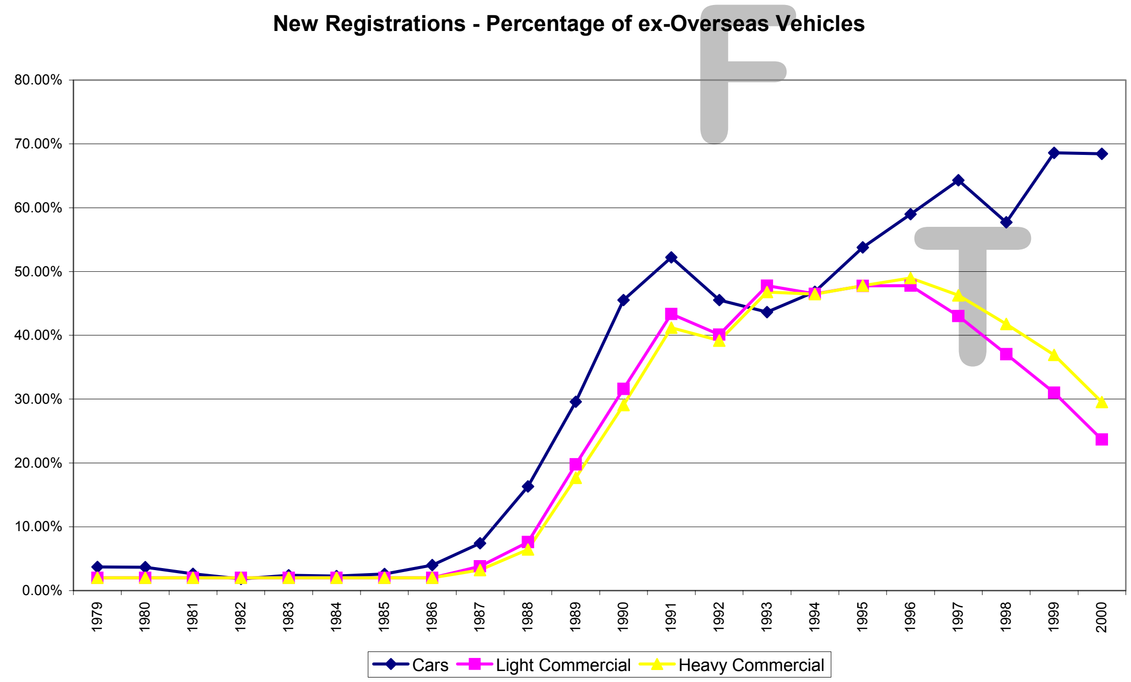


Figure 3.6 - New Registrations, Percentage of Ex-Overseas Vehicles

3.2 Trends in Motive Power and Energy

3.2.1 Market Shares

Motive power for land transport is dominated by petrol and diesel fuelled internal combustion engines. Diesel fuelling has made steady inroads to the light commercial vehicle market and, to a small extent, the car market. However, the use of diesel in cars is far less than in some European countries, such as France where diesel occupies almost half the market. In part this is because most imports are sourced from Japan, but also because the diesel marketed in New Zealand is too high in sulphur to be used in modern European diesel engines.

As discussed further below, gas fuels occupy only a tiny niche in the market. Electrical energy is used to a very small extent – in Wellington trolley buses, the Wellington suburban rail system, and parts of the inter-urban rail network (Central North Island and the Otira tunnel). Other petrol and diesel substitutes and extenders, such as alcohols and alcohol blends, other organic compounds and natural oils have been trialled and proven over the years, but suffer from not being commercially competitive, having no developed user base or distribution network, requiring some modifications to vehicle componentry, and running risks of warranty invalidation.

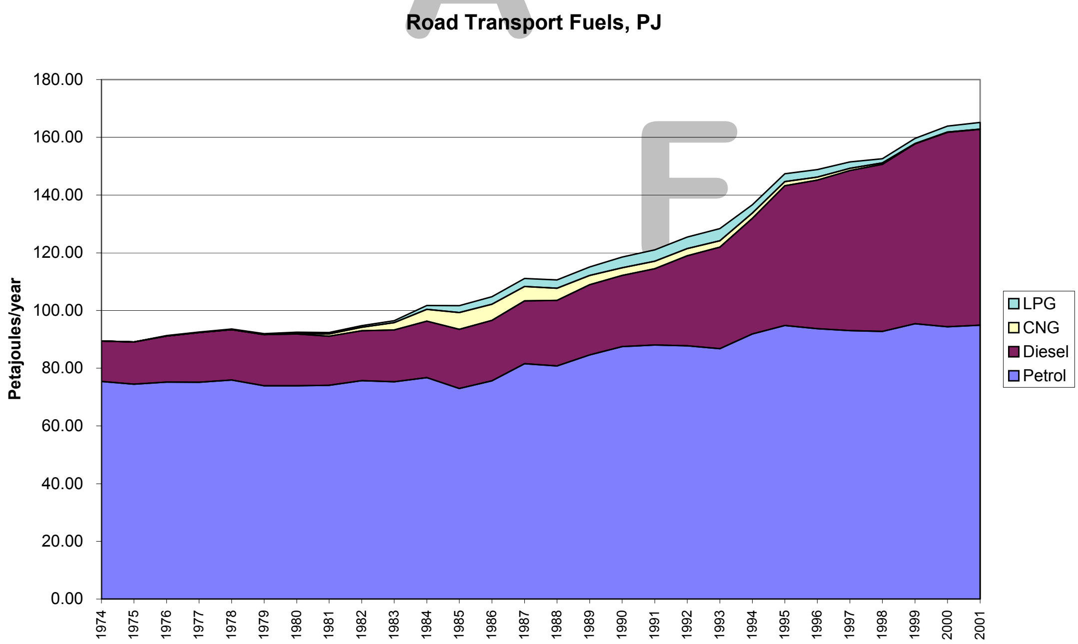


Figure 3.7 - Trends in Motive Power for Road Transport

3.2.2 Alternative Fuels – Experience with CNG and LPG

When considering how new fuels and power systems may penetrate the vehicle fleet in the future, New Zealand's experience with compressed natural gas (CNG) provides an interesting and instructive case study.

The oil shocks of the 1970s prompted the search for fuels to reduce New Zealand's dependency on foreign oil. The Maui and and Kapuni gas fields were producers of natural gas (mainly methane) and liquefied petroleum gas (LPG), a mixture of butane and propane. Both were introduced as alternative automotive fuels and both have emission benefits over petrol and diesel. LPG has found a niche in the market for high utilisation vehicles, such as taxis, where the capital investment in a dual-fuel fuel conversion or a dedicated gas fuel vehicle, can be justified over time by the lower fuel cost. LPG also has the advantage of less tank space and/or greater range between fuelling compared to CNG, which has to be stored as a compressed gas.

The first trials of CNG as an automotive fuel in New Zealand were undertaken in 1978. Conversion of vehicles to CNG began on a commercial scale in 1979

CNG was promoted largely on the basis of the price differential against petrol. The cost of CNG was 36c/l of petrol equivalent compared with a petrol price of 71c/l, effectively halving the fuel cost for the motorist. However, an initial capital cost was involved in the form of conversion kits, which were necessary to convert the vehicle to CNG. A payback time of 18 months to 3 years was predicted based on the upper and lower limits (typically $900-$1,500) of the conversion costs. Generous financial incentives offered by the Ministry of Energy included a 100% loan schemes on the cost of conversion, to encourage entry into the scheme, and a $150 grant on each conversion kit sold. The popularity of the programme was evident by the fact that five years after the commercialisation of CNG in 1979, more than 60,000 conversion kits had been sold and gas sales had increased by 84% (NZERDC, 1985).

However the dramatic growth that saw the number of CNG vehicles nearly double every year, seriously stretched the ability of the industry to cope. Gaps in the refuelling network meant that fuel availability became a major constraining issue for potential and existing CNG users. Also the industry was so preoccupied with meeting the demand for conversion that quality at times became secondary priority, resulting in the perception of CNG as a second-rate fuel which was only used because it was cheaper than petrol (ESMAP, 2001).

In addition to this the CNG program was heavily subsidised by government of the day with promise of continued support until 1987. However, the new Labour Government of 1984 began to deregulate the economy, withdrawing financial incentives for the CNG industry in 1985. This coincided with a fall in the price of petrol and diesel, making CNG unattractive for new vehicle buyers. Gradually the distribution network of CNG refilling stations, which had been built up to cover most of the North Island, began to close down, and now virtually no CNG is sold for automotive use (see Figure 3.8) .

The experience of the CNG programme provides some lessons for the future:

- Government, through public policy and incentives, is able to effect changes in consumer purchasing behaviour, particularly if the public can see a good reason to change;

- The time to introduce a new technological innovation into the transport market in substantial numbers is of the order of 5 to 10 years, once the technology is proven andwith industry support;
- It is difficult to support a technology that is not commercially attractive over a long period of time – subsidies and other financial concessions tend to be short lived and subject and subject to changes of Government and policy.

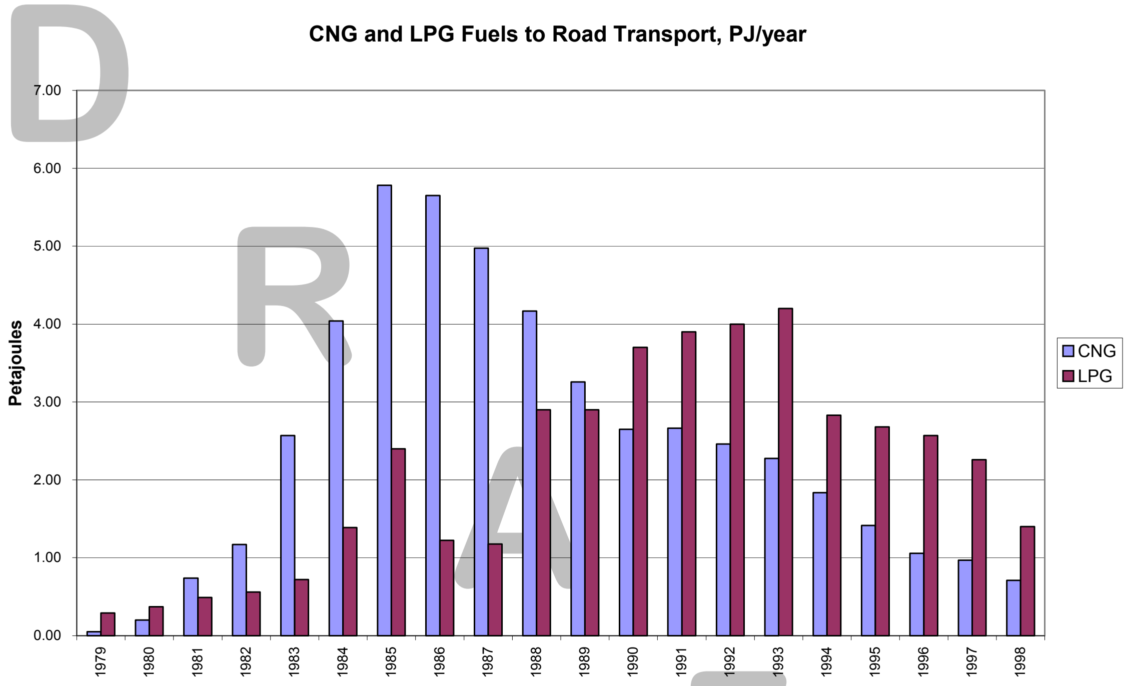


Figure 3.8 - The Rise and Fall of CNG

3.2.3 Energy Consumption by Transport Modes

Figure 3.9 shows the consumption of fuel energy by the main modes of road transport for New Zealand. While car is dominant, commercial vehicles in total consume almost as much end use energy as do cars.

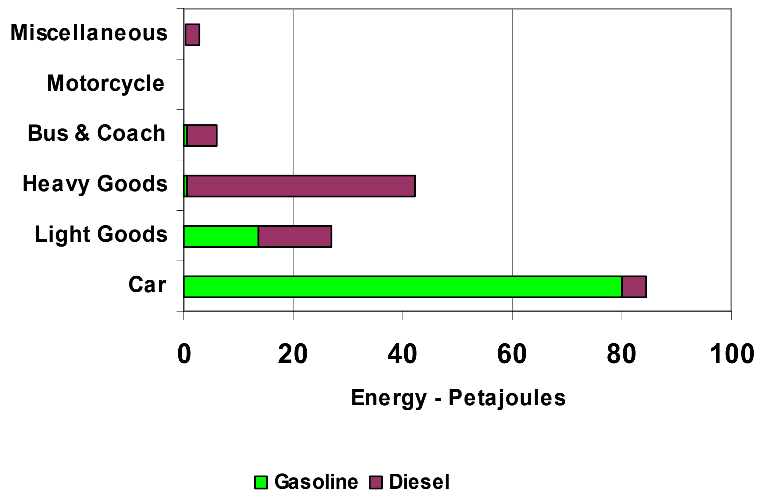


Figure 3.9 - Energy Consumption in Road Transport by Mode

3.3 Consumer Preferences and the Private Car

Car buyers consciously or unconsciously balance a number of factors when taking a decision on car purchase:

- carrying, and possibly, towing capacity depending on the likely use of the vehicle;
- mechanical reliability is generally high on the list;
- safety is increasingly an important choice factor;
- design features, style and interior comfort;
- purchase price and running cost.

Historically, a large family car or station wagon was the typical car of the 60s and 70s. The average new car was over 2.0 litres in engine capacity, heavy, and had quite low fuel economy. The vehicles were simple enough for the home mechanic to do most servicing if so inclined. There was a clear distinction between the car and light commercial vehicle markets. The vehicles had few emission control features, a situation that is not greatly changed as New Zealand has not introduced emission control regulations of the type prevalent in overseas car markets and does not test cars for excessive emissions.

At the time of the 1973 oil shock and through the 1970s, energy efficiency became a concern, and there was a move to smaller engine sizes and lighter vehicles. The average new car engine size came down to 1.7 litres. There was a good selection of very small cars (under 1 litre) on the market.

Through the 1980s and 90s, the situation reversed. Energy prices came down, almost halving in real terms, and consumers started to buy larger vehicles, with features such as air conditioning (almost unheard of pre-1980) and power steering.

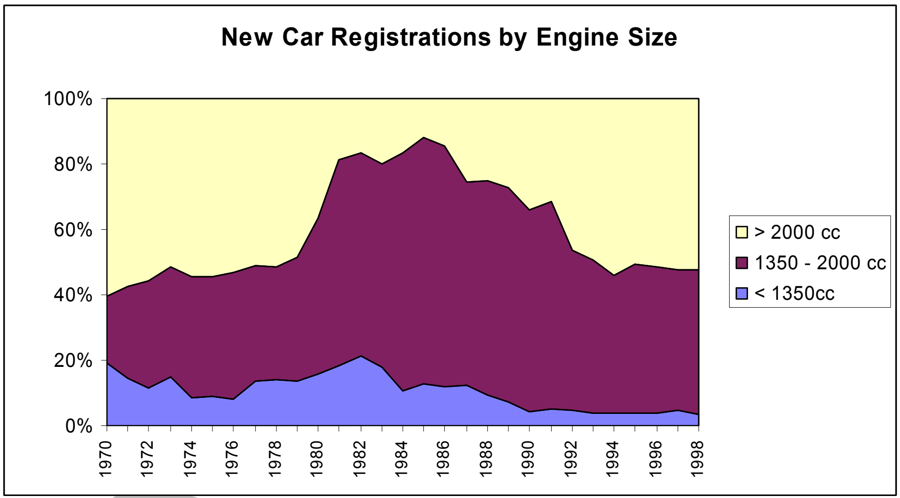


Figure 3.10 - New Car Registrations by Engine Size

In the mid-1990s the sports utility vehicle craze took off, illustrating how a combination of fashion, coupled with the perception of greater safety and heavily supported by supplier advertising can influence a market. Through this period, vehicles have become technologically more complex in regard to their fuel induction, ignition and engine systems, and less amenable to home servicing. The gains made in efficiency of energy conversion have been largely offset by the increased engine capacities, heavier kerb weights and power consuming accessories. There are now very few cars of under 1.3 litres on the market.

The end result has been an improving energy trend from 1974 to 1985, followed by a return almost to the same point by 2001 (see Figure 3.11)

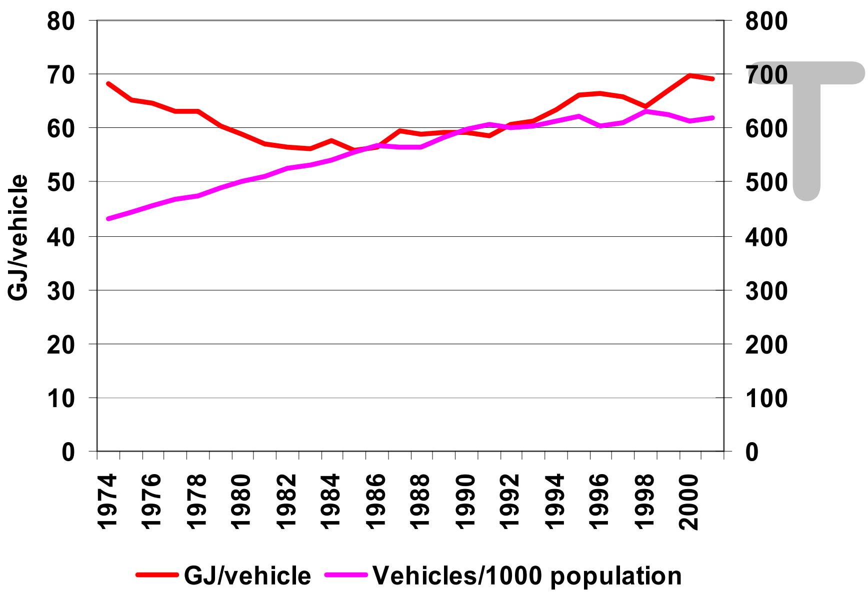


Figure 3.11 - Energy Efficiency of Road Vehicles

The move to large vehicles and semi-commercials has been supported by other factors – increasing demands to carry recreational paraphernalia, to tow boats and other trailers, and for the car to act as a shopping basket to take to the 'big box' retail and wholesale store.

As traffic conditions become more unpleasant through congestion and commuter times lengthen, the car also becomes more of an extension of the home or office and a cocoon for the driver. Cellphones and hi-spec sound systems encourage this trend. The same unpleasant traffic conditions deter motorcycles, mopeds, scooter and bicycles (although, as traffic congestion in Auckland has worsened, the use of motorcycles for couriers, first aid and other service trips has recently increased).

3.4 Fuel Supply, Global Warming and Transport

With the mounting concern about carbon dioxide emissions and global warming, it might be expected that fuel consumption would have a higher priority in the mind of the consumer than it currently appears. Fuel efficiency has shown to be low on the list of factors influencing vehicle choice, and considered really only in regard to its contribution to running cost. However, the link between the long term and somewhat unknown effects of global warming and car fuel economy is probably tenuous in the public mind. Then there is the lack of well-publicised data on fuel economy for models of car (and nothing for the used imports), no requirement for fuel economy labelling, the lack of any evident supply shortage and relatively low cost of petrol, none of which provide signals to consumers that they should change their purchasing behaviour.

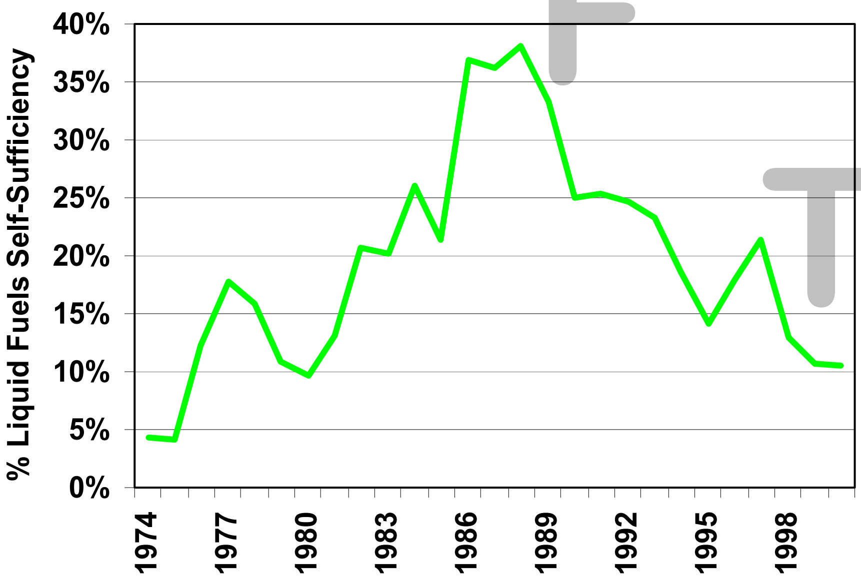


Figure 3.12 - New Zealand Liquid Fuel Self-Sufficiency

Whether this lack of concern will cause a problem in future is somewhat unknown. In common with many other countries, New Zealand is becoming increasingly reliant on overseas sources of liquid fuels supply, the situation which caused a major economic shock in the 1970s at the time of the first oil crisis (see Figure 3.12). The country's reaction at that time, in the face of a doubling in retail fuel prices, was to institute a fuel conservation programme, to design an emergency rationing scheme (which did not come fully into effect, only 'carless days' which were short-lived), to explore for domestic sources of oil and gas, and to investigate alternative transport fuels. New Zealand achieved almost 40% self sufficiency in the late 1980s, but increasing demand, the run-down in heavier liquid fractions from the New Zealand gas and oil fields, the closure of the expensive Motonui synfuels plant, and cheap overseas supplies, have returned the country's self-reliance and risk exposure to its former level.

3.5 Regulation and Taxation of Private Transport

While it almost forgotten now, the New Zealand car market used to be highly regulated and heavily taxed. Cars could only be imported under license, and used cars only if owned by someone returning from overseas, and liable to import duty unless owned for a year. Import tariffs were high and favoured imports from certain countries. The import duties were progressive with engine size, so that a large car from Europe would attract as much as 100% duty. There were strict controls on hire purchase, and loans to buy houses were in short supply, never mind for cars. Despite these constraints, New Zealand still managed to achieve a higher rate of car ownership than most other countries.

The licensing regime was removed and import duties gradually scaled down, abolished, and protection of the local vehicle assembly industry was removed (and the industry rapidly closed down). Later, bulk used car imports were permitted. The overall effect was to very significantly reduce the costs of car purchase (see Figure 3.13).

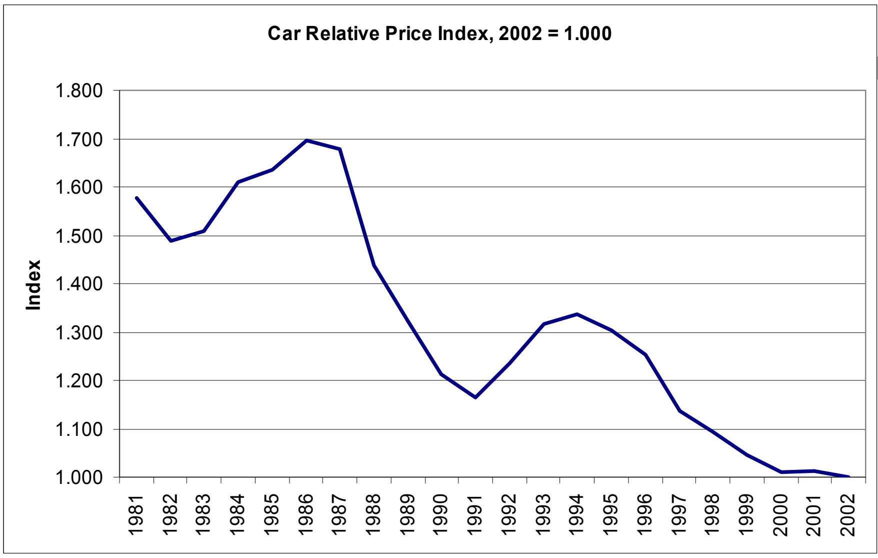


Figure 3.13 - Car Price relative to CPI

3.6 Public Transport

The use of public transport in urban areas declined relative to private transport, and in absolute numbers up to the mid-1990s. There has been a small increase in public transport demand over the last few years in the more congested urban areas although the proportion of urban trips served by public transport continues to fall. Public transport fares have increased at a similar rate to motoring costs, so there has been no strong financial incentive towards greater use, although the evidence is that fare levels are not a major determinant of public transport patronage.

Traffic congestion, increased parking prices and reduced supply, and public transport priority measures can increase the public transport mode share, and are more likely reasons for the slight upturn in recent years. The main markets for public transport have customarily been urban work commuting to and from city centres, as this radial pattern of public transport routes corresponds with the highest demand corridors. The other main market is for school and university students. Public transport is less convenient and less available for bulk shopping trips, for social and recreational travel, for cross-town and out-of-town travel and for weekends and nighttime.

Internationally, conditions that support public transport are urban areas with some or all of the demographic and physical characteristics of:

- large populations and high population density;
- a good existing public transport network and service coverage ;
- well managed and reliable public transport services of acceptable quality for the community, and with sound and sustainable finances;
- public transport service speeds equal to or better than private transport;
- urban topography and land use planning that concentrates transport flows into defined corridors and transport nodes;
- limited space at home or in the city for car parking and high parking costs;
- access restrictions and/or pricing for private transport;
- relatively low established levels of private motor vehicle ownership.

It is notable that even in some relatively poor countries, private transport is often preferred to public transport, but takes the form of cycles, three-wheelers and small motorcycles – this is true of many Asian cities. This is because of the innate advantages of point-to-point travel, free routing and timing, and often lower cost that private transport provides.

International comparisons of public/private transport mode shares are of interest (e.g. Bachels *et al.* 1999) but have to be considered with care. While there are some clear associations between urban density (persons per square km), urban size (population and city radius), infrastructure and service provision (road length per capita, spending on public transport) and use of modes, such global comparisons can be obscured by problems in consistent statistical definition and do not directly imply causal relationships.

For example, as higher levels of public transport use tend to be associated with higher development densities, it is tempting to conclude that creating a higher density urban fabric will induce a higher level of public transport. It may do, or it may not, and whether it does so will depend on a number of other necessary conditions. Whether higher density is necessarily desirable at all needs to be proven rather than accepted out of hand - circumstance will differ from case to case, and may in the end be a matter of social preference rather than of necessity.

There is also a tendency in some quarters to regard public transport as desirable in itself, (and road building bad) rather than to objectively consider the role that each plays in supporting the aims of efficient and 'liveable' urban communities. The same applies in reverse – there are those who regard investing in public transport systems a waste of money. A polarisation into opposing lobbies for public transport systems and road building is not helpful.

A further consideration when drawing lessons for future application from inter-country and inter-city comparisons is that each city's profile reflects that application of 25 to 50 years of growth, investment, physical planning, social economic and political structures. In some cases, cities have been built or rebuilt since 1950, in other cases there has been slower growth and change, or a strong historical legacy of urban infrastructure. Also the record in quality and reliability of public transport services vary widely, and influence patronage.

When looking forward 50 years, the conditions under which future transport planning and investment will occur will not necessarily be the same as those that prevailed in the past 50 years. New Zealand starts from a position of a high level of motorization. There will be limits on the total investment that can be made in transport infrastructure, which in turn will be governed by national economic performance and growth in population. High growth combined with a high level of available investment provides the conditions under which bold decisions can be made in physical transport planning and investment. Low growth and poor economic performance would obviously constrain the level of investment and allow only gradual change.

4 Future Transport Power Systems

4.1 The Outlook for Petroleum Fuels

Changes to the present reliance on fossil petroleum fuels to power transport will be driven by a clear and impending end to the era of cheap and readily available fuel stocks, and possibly by internationally agreed protocols such as the Kyoto Agreement and its emissions trading regimes which set-up financial incentives to reduce consumption. Local air quality concerns appear to be soluble with increased emissions vehicle standards and cleaner burning fuels.

As noted above, New Zealand is in an exposed position to a sudden escalation in fuel prices or reduction in supply, with the most likely trigger being an international conflict of some kind.

Some commentators have estimated that world oil production from conventional sources will peak in the coming decade. The Energy Efficiency and Conservation Authority (EECA) predicts that the market share supplied by Middle East OPEC states will rise from 30% currently to near 50% by 2010 ($EECA_2$, 2000). The International Energy Agency (IEA) forecasts in its world energy outlook till 2030 that oil resources will be ample, but more reserves will need to be identified in order to meet rising oil demand and new sources of energy and advanced technology will emerge during this period (IEA, 2002). The IEA predicts that global oil demand is set to rise in the next thirty years, with almost three-quarters of the increase in demand coming from the transport sector. The New Zealand Ministry of Commerce predicted a similar pattern for New Zealand over the next twenty years (Ministry of Commerce, 2000).

Thus, while the world is not 'running out of oil' in the near future, the issue is one of potential price instability and volatility caused by re-adjustments in the international supply-demand balance. With imported oil use in New Zealand projected to continue to grow over the next two decades this further dependence carries certain risks ($EECA_2$, 2000). There are also risks within the New Zealand energy system as growing energy demand is highlighting constraints on some links of the energy supply chain.

In addition, New Zealand's transport sector is now responsible for the largest single share of CO_2 emissions derived from fossil fuel combustion. At the end of 2000, this figure stood at 45%, compared to an average of 30% for OECD countries. With the ratification of the Kyoto Protocol, this will pose significant challenges for the transport industry, particularly the role of conventional fuels, in the future.

In short, current trends of fossil fuel usage are unsustainable in the long term, but may be so for the first 25 years of the new century.

What would the scenario be in 50 years time? Moving to a carbon-free world would require simultaneous advances in both automotive fuels and propulsion systems. Initially this would involve improving energy efficiency and moving in the long term to renewable sources of energy ($EECA_3$, 2000)

4.2 Emerging Technologies

4.2.1 Power Density and Energy Density

The great advantage of the internal combustion engine lies in combining a high energy density (energy stored per kilogram) with high power density (kilowatts per kilogram). While the ICE is not particularly efficient in converting the chemical energy content of the fuel into mechanical output from the engine, the relatively light weight of engine, fuel storage and delivery system still outperform most rivals. The ICE, with appropriate gearing is flexible in its output range of power and torque, and is able to deliver the acceleration required by the car driver.

Any new system has to be able to match these characteristics if the new technology is to co-exist alongside ICEs over the transition period.

4.2.2 Likely Technologies

The two main technologies competing to become the next step in road vehicle power systems are:

- Hybrid Vehicles – combining internal combustion engine technology with an electric motor and regenerative energy storage, or
- Fuel Cell Vehicles – powered by electricity produced by reverse electrolysis using hydrogen, methane or methanol as the motive fuel

Electric vehicles relying solely on storage batteries have been researched for decades but have never overcome the problem of low energy density (although power density is good), and the deadweight and range limitations that this imposes on a battery-electric vehicle.

4.2.3 Hybrid Vehicles

A disadvantage of the petrol engine is that it must be designed to deliver acceptable power over the range of torque and this inevitably leads to compromises and a less efficient solution than if the engine were able to operate at a constant power output and speed as, for example, a diesel-electric rail loco.

The other disadvantage is the inability of the petrol engine to use the energy available when braking – this has to be dissipated as heat.

Hybrid vehicles provide a solution that overcomes both of these problems. A small ICE optimised to a constant duty cycle, also enabling low emissions, generates electrical energy and which is directed either to the roadwheels or, if demand is low, to an on-board battery. Why energy demand is high, the battery supplies the extra energy required at the road. When braking, the system has regenerative capability to return the kinetic energy of the vehicle into electrical energy and battery storage.

A hybrid can run one any fuel suitable for an ICE. A New Zealand example is the Designline hybrid shuttle bus in Christchurch is powered by LPG, shown below.

Widespread penetration into the auto market hinges mainly on the economics of producing a complex hybrid power system, rather than inherent capabilities of the technology itself. The hybrid's complexity, and the fact that the best storage and conversion systems have yet to be fully developed, is responsible for varied opinions on hybrids' ultimate impact in the marketplace (USDOE, 2002).

Figure 4.1 - Designline hybrid shuttle bus in Christchurch (Source: Designline, 2000)

Commercialisation of hybrids is already underway. The Toyota Prius (shown left in Figure 4.2) has sold 100,000 units since it was first put up in the Japanese market in 1997 (Toyota, 2002). New Zealand's sole experience with the hybrid car was the donation of one Prius to the World Wildlife Fund in 1999.

However, working with the new technology has had Honda lose money with its hybrid vehicle, the Honda Insight (shown right in Figure 4.2). Nevertheless, in general agreement with industry, the development and sale of hybrid technology is considered viable in the long term because it is largely seen as the bridge between conventionally powered vehicles and fuel cell vehicles powered by hydrogen.

Figure 4.2 - Toyota Prius and Honda Insight

Plans for making hybrids commercially available in New Zealand are unclear, but Toyota New Zealand's sales manager expects fuel cell vehicles and hybrid vehicles to challenge conventionally-powered vehicles for market share within five to ten years (pers comm. Toyota, 2002)

4.2.4 Fuel Cell Vehicles

The principles of the fuel cell were first demonstrated by British physicist Sir William Grove in 1839. However, with the internal combustion engine gaining popularity, the concept fell into oblivion until it was revived by NASA scientists as energy technology for their space program (Autoweb, 1997).

A fuel cell is a power plant that produces electricity without combustion. Chemical energy is converted directly into electrical energy and heat when the two reactants are combined. In a hydrogen/oxygen fuel cell, stored hydrogen is combined with oxygen from the air. Water vapour is the only by-product. No pollutants are produced if pure hydrogen is used as the fuel.

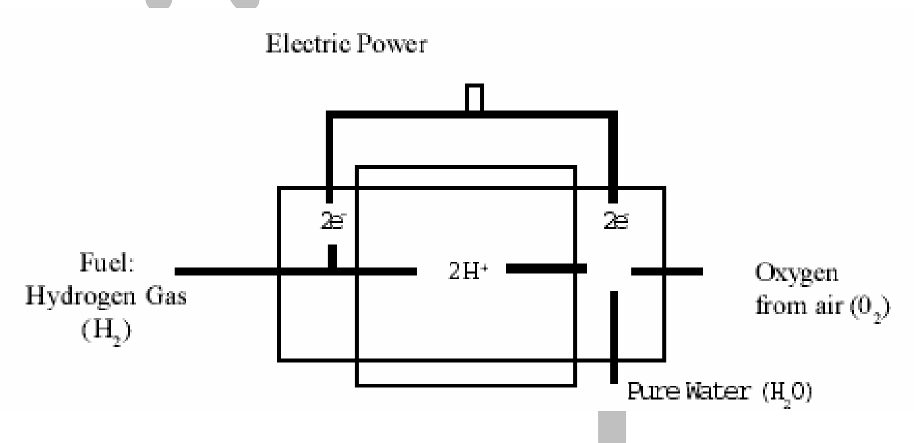


Figure 4.3 - How a Fuel Cell Works

In addition to being a clean, and effectively zero emission power source, the efficiency of conversion between chemical energy and electrical power is much greater than can be achieved with an ICE.

A difficulty with hydrogen is that, as the lightest of gases, and potentially explosive, it is difficult to store. While compressed pressure cylinder storage is possible, in the same way as natural gas is stored as CNG, there are the problems of bulk and weight of the cylinders, although the greater efficiency of the fuel cell offsets this to some extent. Other possibilities are cryogenic storage and solid chemical storage as hydrazine. However, for demonstration versions of fuel cell vehicles, the method favoured by developers such as Daimler-Benz is to reform hydrogen from a liquid fuel such as methanol on board the vehicle.

Fuel cell vehicle demonstrations date back to May 1994 when Mercedes Benz unveiled its first methanol fuel cell car – the NECAR I. Two years later the unit was accommodated into a passenger car – NECAR II (shown in Figure 4.4 below). In 1997, they released their first fuel cell bus NEBUS, which has been used as a prototype for the Daimler-Benz Citaro Fuel Cell Buses (shown in Figure 4.5).

Figure 4.4 - Daimler-Benz Fuel Cell Car – NECAR II

Figure 4.5 - Daimler-Benz Citaro Fuel Cell Bus

30 Citaro buses have been sold to ten European cities – Amsterdam, Barcelona, Hamburg, London, Luxemburg, Madrid, Proto, Stockholm and Stuttgart and Reykjavik – as part of the Clean Urban Transport for Europe (CUTE) hydrogen infrastructure demonstration project. Reyjkjavik, Iceland forms part of a sister project – ECTOS (Ecological City Transport System).

Each of the nine operators in the CUTE project will install a different hydrogen supply using different production methods (Daimler Chrysler, 2002). Whereas the main is to find practical ways to provide hydrogen fuel which is specific to various situations, the project will also provide valuable analysis of the technology status of fuel cells.

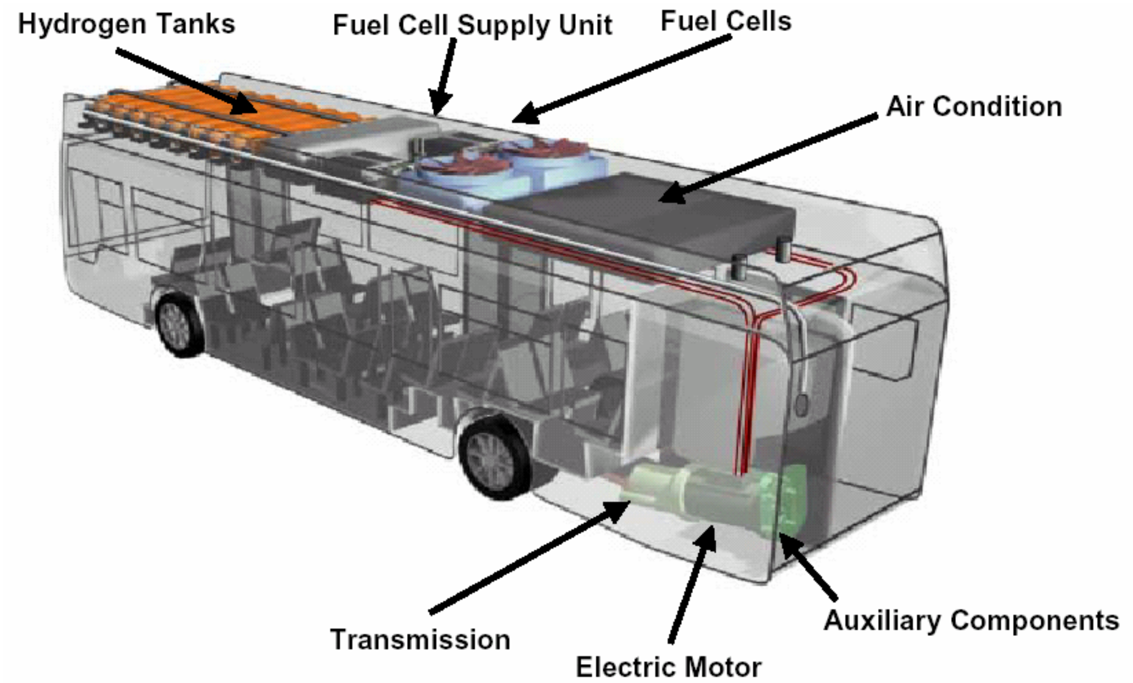


Figure 4.6 - Hydrogen Fuel Cell Bus Components (Source: Jones, 2002)

In the USA, the California Fuel Cell Partnership (CaFCP) is a collaborative effort between auto manufacturers, energy companies, fuel cell technology companies and government agencies aiming to demonstrate fuel cell vehicles under day-to-day driving conditions. The Partnership expects to place up to 60 fuel cell vehicles on the road by the end of 2003, and is investigating the local market for this new technology (CaFCP, 2001).

Figure 4.7 - Honda FCX – First Fuel Cell Car Certified for Commercial Use

Honda FCX is the first fuel cell car that is certified for commercial use and was leased to the City of Los Angeles in December 2002. The delivery of four more vehicles is planned for 2003, with Honda planning to lease up to about 30 fuel cell cars to California and Japan over the next two years (Honda, 2002).

4.2.5 Development Path

The fuel cell is currently expected to become the universal source of propulsion in the future with hybrids being a transition step. Below is the prediction made by one auto company.

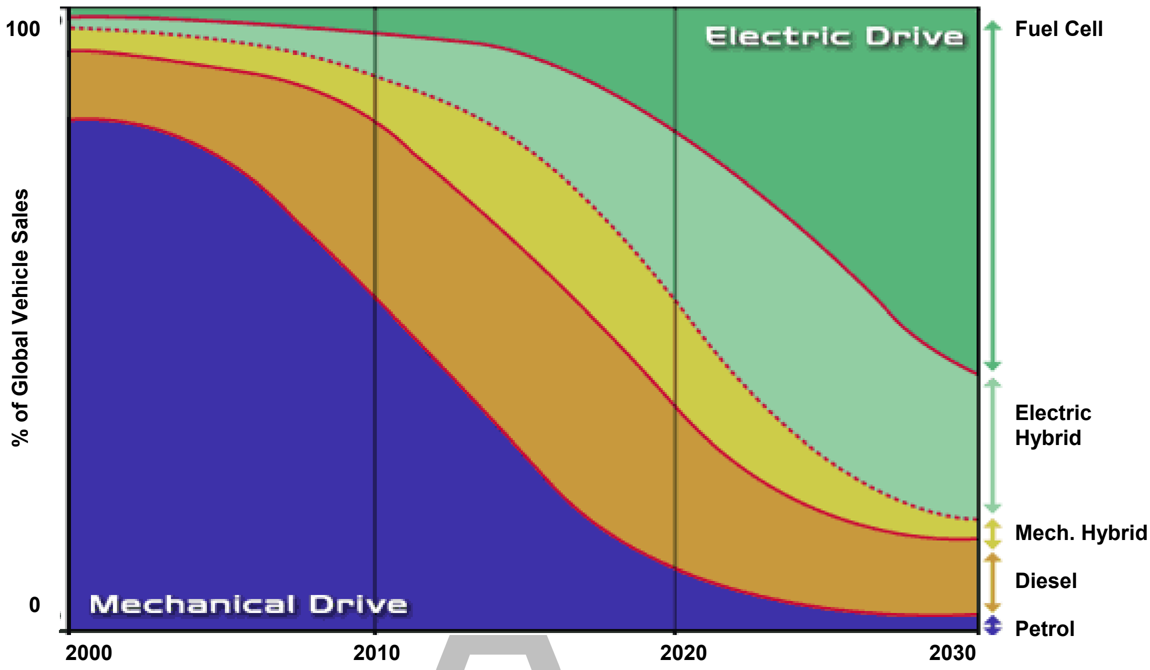


Figure 4.8 - Predicted Evolution of Vehicle Engine Types (Holden Advanced Engineering)

There are significant challenges to be met before fuel cell vehicles can be commercialised. There are issues of fuel cell cost, systems integration and control, but the principle technical obstacle appears to be the development of practical and cost-effective on-board reformers to produce hydrogen required by fuel cell. Also, hydrogen refuelling infrastructure is yet to be developed and therefore on-board reformers are likely to be used in the initial stage of commercialisation to extract the hydrogen from liquid fuels (e.g. methanol, ethanol, and gasoline).

Obstacles are due not only to the inherent technical complexity of the reforming process but also to the unique challenges of the on-board environment. Although methanol reforming is less technically demanding and may be more advanced on its development to date compared to gasoline and ethanol, all on-board fuel reformers face major challenges of economic feasibility even after technical success is achieved (Benvilacqua Knight Inc, 2001).

4.3 Alternative Fuels & Transition Scenarios

Deciding upon the optimal fuel for the future is dependant on a range of performance criteria including local emissions, greenhouse gas emissions, safety, the availability of raw materials as feedstock, and costs. This serves to complicate the assessment process and therefore value of each choice of fuel has to be established on case-by-case basis (IEA, 2000). A comparison of the relative advantages and disadvantages of fuels presently used and those under active research and development is given in Table 4.1.

Table 4.1- Comparison of Fuels

Reduced Carbon Content

	Fuel	Production Method*	Advantages**	Disadvantages**
Present (Developed Infrastructure)	Petrol & Diesel	Refined from crude oil	Comprise 99% of New Zealand's transport sector, i.e. existing infrastructure	Continued use of fossil fuels environmentally unsustainable Issues of energy security Liquid fuels are non-biodegradable
Present (Developed Infrastructure)	LPG	Field: Separation of natural gas liquids, fractionation to LPG Refinery: By-product of crude oil refining, fractionation to LPG	Lower particulate emissions than petrol and diesel Higher energy efficiency compared to petrol Mature technology	
Present (Developed Infrastructure)	CNG	No conversion; dried and purified as necessary	Cleanest burning fossil fuel Mature technology Infrastructure exists Feedstock for hydrogen in fuel cell vehicles	
Transition (Infrastructure under research &	Methanol	Steam methane reforming or gasification of biomass, produces synthesis gas which is converted to methanol.	Reduced emissions Most common fuel for fuel cell vehicles in its role as hydrogen-containing feedstock. Potential to be renewably sourced	Low conversion efficiencies from biomass Decreased fuel economy compared to petrol Groundwater contaminant. Methanol vehicles have stopped being made.
	Biofuels	Biodiesel: vegetable oil extraction, esterification	Can be used in existing diesel vehicles. Biodegradable. Renewably sourced.	Increased nitrogen oxide emissions compared to diesel
		Ethanol: hydrolysis of biomass to glucose, fermentation of sugar	Added to petrol to improve emission quality Feedstock for hydrogen in fuel cell vehicles. Renewably sourced.	Decreased fuel economy compared to petrol
	Dimethyl Ether	Production of synthesis gas from natural gas or biomass, then oxygenation	Lower emissions compared to LPG/diesel Renewably sourced	In very early stages of development
Future?	Hydrogen	Gasification or reformation of hydrocarbons (e.g. coal, methane, methanol) Electrolysis of water	Zero emission of criteria pollutants. Ability to be produced from variety of resources. Potential to be totally sustainable energy source if produced from renewable electricity.	Lack of infrastructure and hydrogen compatible vehicle systems i.e. radical changes in fuel and infrastructure technology needed.

* Source: International Energy Agency[2] (IEA), 2000. ** Alternative Fuels Data Center, 2002.

However, technologies using conventional fuels will develop as well. Comparing alternative fuels against conventional fuels today becomes a comparison against a moving target and alternatively fuelled vehicles will have to keep up. Technology for conventional fuels like gasoline and diesel has matured to a known extent while that for alternative fuels is still developing, therefore a fuel comparison is never completely fair (IEA_2, 2000).

In addition, assessing a fuel's usefulness in automotive applications, the outcome depends on time. Some fuels already have extensive use, while others remain as prototypes. Yet for long-term planning, fuels still not fully developed hold as much interest as those in or near current use. They too require evaluation because expectations for the future can influence current strategy (IEA_2, 2000).

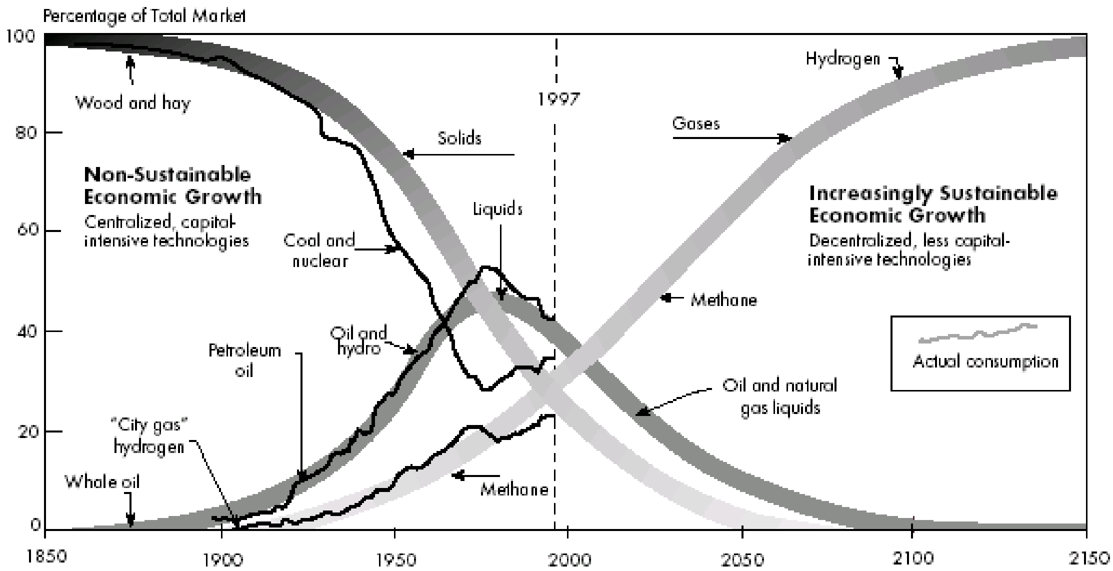


Figure 4.9- Global Energy Transitions 1850-2150 (Source: Dunn, 2001)

4.4 New Zealand Policy Direction

Eco-efficient vehicles and fuel options form one of six goals under the Action Plan for Transport in the National Energy Efficiency and Conservation Strategy (NEECS) put out by EECA. Three main measures are stated to achieve that goal:

- Long Term: Introduction of eco-efficient vehicles with the objective to transform the technology and energy systems powering the transport fleet
- Short Term: Vehicle Efficiency Standards and Related Measures with the objective of reducing the average fuel consumption thereby improving the energy efficiency of the New Zealand vehicle fleet, and
- Short Term: Vehicle Fuel Consumption Information with objective of providing fuel efficiency information to encourage the selection of more energy efficient vehicles (over short term).

The rest of the goals prescribed in achieving a more energy efficient transport sector in New Zealand include travel and demand management, road pricing, using more energy efficient modes, energy efficient road networks and traffic management, and public education.

New Zealand's Renewable Energy Target, a sister document to NEECS specifically states the reviewing fuel taxes on bio-ethanol/petrol blends and focusing on the hydrogen/fuel cell pathway and how New Zealand can maximise benefits from its involvement (EECA$_3$, 2002).

In addition, the Foundation for Research and Science Technology (FRST) in conjunction with Industrial Research Limited (IRL) have launched a hydrogen research program with an annual budget of $1.2 million. It aims to provide New Zealand with a technological basis to initiate development of a hydrogen energy infrastructure, and through emphasis on demonstrating new hydrogen based energy technologies, attracting investment from energy stakeholders (IRL, 2002). The programme's main themes are:

- Development of technology to deliver distributed electricity supply from New Zealand coal, through hydrogen production and fuel cells, and
- Development of a capability for production of distributed hydrogen by electrolysis from renewable energy.

5 Intelligent Transport Systems

5.1 Introduction

Intelligent Transport Systems, or ITS, is a term used to describe a wide range of communications and information technology development applied to the transport sector[1]. Some of these technologies are already influencing transport demand and traffic management, and their influence will become more prevalent in future.

5.2 Elements of Intelligent Transport Systems

Elements of ITS that are likely to have an important influence on transport technology and the way that it is used are:

- vehicle positioning systems (VPS) – global positioning by satellite (GPS) allows any person or vehicle equipped with a receiver to accurately locate their position on the globe; the accuracy has improved markedly since the US lifted the selective availability which limited the accuracy of civil systems bringing them up to a near military standard;
- digital mapping and geographic information systems (GIS) – there are already several commercial versions of digital maps that can be used for information and navigation, or stored within a vehicle's on-board computer so that GPS positioning can be compared against information stored on the local environs;
- automatic vehicle guidance and control – technology that has long been accepted in aviation, is widely used in rail transport, is now starting to penetrate road transport – for example through proximity warning and automatic braking systems; in future such technology may allow private vehicles to be marshalled into virtual "trains" at closer inter-vehicle spacing than can be safely maintained by individual drivers; vehicle routing may also become semi- or completely automatic; fully automated highway systems (AHS) is a possible ultimate goal;
- transport user information systems – real-time information on available transport services, such as road conditions, shortest routing, public transport passenger information
- intelligent road networks – providing the ability to manage demand and, in conjunction with automatic vehicle guidance, to allocate vehicles to routes in a way that makes best use of network capacity. This is a continuation of the development of traffic signalisation and control, starting with fixed-time signals, adding vehicle actuation, evolving into adaptive area-wide control systems such as SCATS, integration with Advanced Traffic Management Systems (ATMS) into systems that will

[1] IHVS – Intelligent Highway and Vehicle Systems is another commonly used term covering a similar field

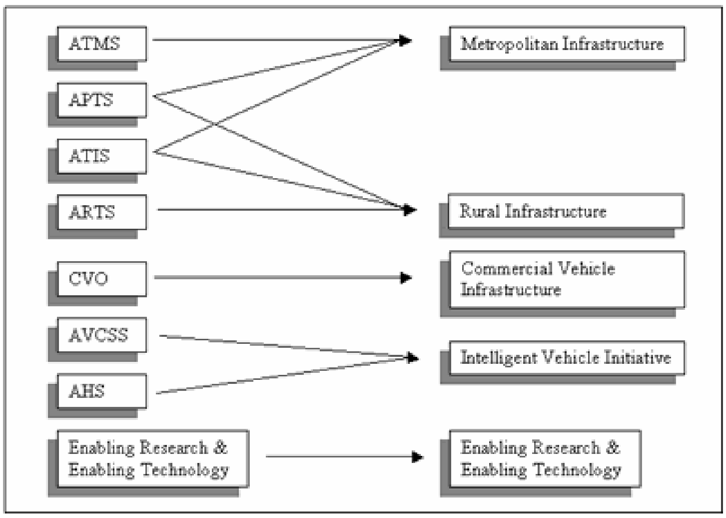
eventually provide automatic control and demand management over areas of the road network.

- network access control and charging – as telephones and power are charged for by quantity and time of use, so is the use of parts of the road system likely to be charged for in the future; charging basis may include features of the road (related to maintenance cost), features of the vehicle (such as size, weight, nature of goods or passenger carriage, emissions profile), and time of day (for congestion and environmental charging).
- in the area of freight transport, automatic stock control systems linked to warehouse picking and despatch, and reaching back through the production and distribution chain, allowing stockholdings to be minimised and just-in-time delivery;
- broadband and wireless communications – high bandwidth communication via optical fibre or wireless systems are an important enabling technology supporting ITS; data transmission and central processing requirements for many of the systems are high, and some have to operate in real-time; dedicated short range communications (DSRC) for exchange of information between vehicle and roadside detectors using a range of wireless communication techniques;

5.3 Overseas Developments

5.3.1 USA

A major research and development programme was initiated in the USA in 1991 under the research-focused Intermodal Surface Transportation Efficiency Act (ISTEA). This was followed in 1998 with Transportation Equity Act for the 21st Century (TEA-21) which restructured the programme into broad categories of intelligent highways and intelligent vehicles and is deployment-focused (DOT 2003). Under TEA, there are a number of coordinated and cross-cutting development programmes sponsored by the US Department of Transport as shown below:



Three have an urban focus including: **Advanced Traffic Management Systems (ATMS)**, **Advanced Public Transportation Systems (APTS)** and **Advanced Traveller Information Systems (ATIS)**.

The **Advanced Rural Transportation Systems (ARTS)** Program includes "the application of technologies under development for metropolitan and commercial vehicle infrastructure that are adaptable to rural community needs".

The **Commercial Vehicle Operations (CVO)** program is focused on the deployment of Commercial Vehicle Information Systems and Networks (CVISN).

The **Intelligent Vehicle Initiative (IVI)** is focused on deployment of advanced driver assistance systems. The emphasis in the IVI programme is on automated vehicle and driver safety systems, particularly vehicle control and collision avoidance under normal and degraded driving conditions. The program also seeks to ensure that in-vehicle technical systems, such as navigation, information and warning systems, cellphone use *etc*, do not compromise driver and passenger safety.

This is a different approach from the earlier **Automated Highway and Vehicle Systems** demonstration project in 1997 funded under ISTEA which resulted in a well-publicised field demonstration in San Diego by General Motors and Delco Electronics of instrumented cars joining into close spaced platoons on the roadway under normal highway conditions, and then de-linking and proceeding under normal driver control. The control system used a combination of radio frequency communications, cameras, and magnetic stripes on the road. The equipment cost was US$20,000 per vehicle and it was estimates would have to reduce to $1,000 before such a system would be commercially viable. A planned full-scale demonstration project was planned for 2002 but was cancelled.

A number of theoretical studies have been made into the route capacity increases possible under a fully specified AHVS for motorway sections – increases of capacity by two to three times the capacity for an unautomated highway have been suggested (see for example Maciuca and Hedrick, 1995;)

The emphasis now appears to have gone away from these more ambitious AVHS projects for the time being and into the single vehicle safety and collision avoidance programme as being of higher priority and an intermediate step to a full AVHS system at some later date. This includes "intelligent cruise control", which provides an override against unsafe driving behaviour such as speed at hazard locations, following too close etc. The approach is problem-based to improve road safety rather than explicitly to automate the highway/vehicle system for capacity purposes.

Future: The short term programme under the TEA runs to the end of 2003, with the aim of deploying a number of these technologies under full operating conditions. A longer term R&D programme is being pursued for the 20 years beyond this.

These various programmes tackle separate areas of application of ITS. Work is also going on to develop standards and protocols for systems inter-operability and later integration of these largely independent developments.

5.3.2 Europe

[to be written]

5.4 New Zealand Developments and Uptake

Many of the elements of ITS are in a developmental stage in New Zealand. Some examples are:

- vehicle positioning systems – GPS vehicle positioning is now widely fitted in higher specification cars for on-board navigation and security tracking. Trucks and buses are also being fitted with such systems for fleet management, despatching and as part of passenger information systems[2];
- digital mapping and GIS – there are three or four digital or electronic maps of the state highway system and an increasing level of coverage of the local road network. These include both cadastral boundary maps and road centreline maps;
- automatic vehicle guidance and control – so far has not made any significant entry to the NZ market, although some higher spec vehicles are now being fitted with forward facing proximity warning devices;
- intelligent road networks – Auckland and Wellington are developing ATM Systems on the motorway networks involving closed circuit camera surveillance and variable message signing. Ramp control and linkages with the city SCATS network is the next stage, providing a start to active demand management;
- road access and charging – the Ministry of Transport is actively investigating electronic systems for charging heavy vehicles for road use as a development of the present mechanical/paper based system – such systems would be GPS and electronic map based and eventually could charge for road space by segment, time of day and by other chosen vehicle, traffic or road characteristics; and the metropolitan councils are investigating electronic pricing as a congestion management and/or revenue mechanism

Transit New Zealand has published an ITS strategy setting out goals, role and an action programme which includes:

(i) Advanced Traveller Information Systems – including Variable Message Signing, distribution of emergency and other route information by website and cellphone and via in-vehicle navigation systems – a watching brief is being kept on overseas developments

(ii) Urabn area ITS including extension and development of the ATMS systems and integration with SCATS, ramp metering, tunnel flow control, incident detection and management

[2] A New Zealand company NAVMAN is a world leader in this field.

(iii) Public Transport Systems – signal pre-emption, HOV lane control, passenger information systems

(iv) Rural and regional ITS – for traveller information and safety on inter-regional and rural highways - weather information, safety systems, avalanche and slip warning

(v) Commercial vehicle ITS – load/weight management, commercial vehicle routing information, vehicle location/fleet management

(vi) Data systems and national level integration

The programme parallels ITS development overseas, at a level and content consistent with New Zealand's road and traffic conditions.

ITS involves roads, drivers and vehicles, so new developments require a partnership approach between the transport industry, the private motoring public and the Government agencies involved - Transit, other Road Controlling Authorities, Regional Councils, LTSA, Police and Ministry of Transport.

5.5 Impacts of ITS to 2051

The overall potential effects of ITS can be summarised as:

- higher levels of information available to the traveller or goods consignee on the status of the transport network, on available transport services, and on matching travel requests with services; this should allow vehicles to achieve higher occupancies and load factors, so moving the traffic more efficiently and at a lower requirement for roadspace;
- active management of the network will enable those more heavily used sections to be operated at a higher degree of utilisation than can be achieved with an unmanaged unrestricted access system – the result should be the ability to run close to system capacity without excessive congestion delays; better incident management through advance rerouting and metering;
- in the short to medium term, intelligent vehicle and highway systems are likely to be aimed primarily at safety improvements such as vehicle control overrides in near crash situations, in-vehicle warning systems and roadside warning systems
- if automatic vehicle guidance and control systems eventually become a reality, probably a longer term prospect, these hold the promise of increasing high volume highway flow capacities (two to threefold in a fully-fledged system) for parts of the network.

6 Future Transport Modes

6.1 Introduction

One view of the future is that the profligate use of fossil fuels and other exhaustible natural resources by an ever-expanding proportion of the world's population will eventually be halted by constraints of scarcity, escalating cost and environmental degradation – with either a soft or a hard landing. The private car is often seen as a casualty of this inevitable transition at some point in time to a future based on sustainable use of resources, extensive recycling and reuse, managed population growth and, at the risk of introducing political overtones, a move away from an individualistic private property culture back to one based more on community values and sharing.

If such a future lies within the Smartgrowth time horizon, then the question may be asked how will this future transition influence development of the built environment and transport systems, and should we be anticipating these changes now?

In this section we advance some ideas on how the use of transport modes may change, whether there will be a radical shift in the balance between private and public transport, and what the mix of transport may be may be in 50 years' time and how it will be used.

6.2 Essential Characteristics of Transport

The essential features that are sought from modes of transport are:

- door-to-door service - every person trip has a start and an end that involves walking. This may be to the carport, the bus stop, to the bicycle park, but is required nonetheless;
- personal safety and security – are an important consideration, and one of the reasons why some modes of transport are not better used; safety and security of travelling companions, particularly dependents is also important;
- ease of use, comfort, weather protection and pleasant travel conditions;
- ease of carrying goods, luggage, shopping – a major reason why public transport is little used for shopping trips
- flexible scheduling, reliability in journey start and end time, and an acceptable trip duration;
- ability to make use of in-travel time;

For the transport of goods, the required features have some similar parallels:

- door-to-door service: the goods have to be loaded and unloaded and there must be facilities and space to do so for the type of vehicle used; at the end consumer end there is the question of how the goods get to the household and, for the waste stream how refuse and recyclables are collected;

- goods must be protected against damage, theft and loss, the extent of the protection depending on the goods' value, fragility, perishability and hazardous nature;
- with more reliance on just-in-time delivery to minimise inventories and storage, freight customers are looking for reliability and regularity of service, while transport operators look to minimise the vehicle fleet size and maximise load factors to keep costs low.

6.3 Private versus Public Passenger Transport

Concerns about congestion, emissions and safety problems attributable to private transport, meaning the private car, leads many to advocate a much greater future role for public passenger transport in the expectation that this will be more resource efficient and less polluting.

It was demonstrated in a landmark study as long ago as 1963, that unrestrained growth in car use could not be accommodated within moderate to high density urban development typical of older European cities 3 and that to do so either requires constructing the transport network on multiple levels – either elevated or below ground. High levels of car ownership which maintain acceptable standards of accessibility require wide road reserves and multi-lane arterial systems at regular intervals through the urban fabric.

While New Zealand's urban development is not of the same density, there is nevertheless an historical legacy of relatively narrow arterial road reserves, and many topographic constraints in the older established urban centres and suburbs. Policies of intensification, predicated on the increased use of public transport serve to increase the demand on road networks of limited capacity in an era when many people own cars. These older areas were built in an era when relatively few families owned cars, when public transport was the only option for travel over any distance, and household supplies were mainly delivered to the door.

On the urban periphery and in new suburbs, the opportunity exists to develop road transport networks with the capacity necessary to accommodate high levels of car ownership and reliance. However, the problems of routing this traffic into or through the higher density urban centres remain. When the city centres cannot cope, the natural response is for satellite urban areas to increase in relative importance, effectively creating multi-centred conurbations.

When considering transport's future role, an important constraint is the existing urban fabric and the rate at which new building or redevelopment can take place. Over a 50 year time horizon, the high growth areas of the North Island are expected to roughly double in population, so this is an indication of the extent of new development that can take place. There may be some opportunity for infill in areas already developed if this is considered desirable, and limited opportunity for comprehensive redevelopment.

[3] Traffic in Towns, Report of the Steering Group and Working Group Appointed by the Ministry of Transport, HMSO 1963

Clearly, new development can be managed in ways that provide some advantage to public transport, for example by increasing densities at nodes along transport corridors, while other development patterns may provide little such incentive.

When considering the future extent of public transport's role, the potential size of the market must be considered and the constraints that will influence both private and public transport modes.

6.4 New and Novel Transport Systems

Barring some unexpected discovery in physics, the likelihood of an entirely new transport system being invented over the next 50 years seems unlikely. There are of course many systems that have been tried in the past with varying success, or have been already been under development for many years but struggle for commercialisation against high cost.

6.5 Future Role of Private Transport

Private transport faces the dilemma of an ever increasing demand for car ownership in conflict with limits on the continual expansion of highway and street networks. In the future, the access to roadspace is likely to be managed by a combination of regulation and pricing.

At present though, most private vehicle travel in New Zealand is by car and, for commuting journeys, in cars with very low occupancy. Part of the reason for this is that cars still tend to be multi-use – purchased with a view to being weekend campervans, shopping baskets and weekday commuter transport all in one. Also there has been a tendency to fortify the car against intrusion and impact rather than to render the external travelling environment safer and more pleasant.

Small cars, which used to be prolific, are now seldom seen. The urban traffic environment, by and large, has become more hostile to less or unprotected road users in or riding small vehicles. Those using motor scooters and cycles are at much higher risk of accident than car users. Larger trucks are being used which are intimidating and create side draft, traffic lanes have been narrowed to increase capacity where widening is difficult to achieve, and footpaths have been reduced to create more roadspace.

Some cities have managed to provide a wide range of transport modes, including various forms of public transport, and private cars while still providing protected and environmentally pleasant routes for cyclists and pedestrians – Stockholm is a good example. However, this has come through many years of conscious physical planning. Other cities are trying to retrofit facilities that promote walking and cycling over short to medium distances in urban fabrics that have been largely taken over by motorised traffic.

In future, advanced materials and propulsion technology will already allow new forms of non-motorised transport and low-impact motor assisted transport to substitute for some of these low occupancy commuter trips that are currently made by general-purpose cars. This will include safe low speed transport infrastructure for the young cyclist and the old person's mobility scooter. However, the networks to support individual low impact transport intermediate between walking and motoring are largely absent. Apart from being more environmentally acceptable, healthy and low cost, these intermediate single-person transport vehicles give the free-routing on-demand benefits that public transport struggles to provide. Contrary to expectations, part of the future transport solution may lie in *higher* levels of personal vehicle ownership – but with a better matching of the type of vehicle needed with the nature of the trip.

[….. still developing this]

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