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The spread of technologies through the vehicle fleet

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Abstract

New vehicle technologies, not surprisingly, show up first in new vehicles. To understand how they spread to a proportion of or all vehicles in the fleet, requires conceptualisation and measurement of two stages. The first is the pattern and timing of the spread of the technology in question through the new vehicle sales. Then fleet models (for instance BITRE's CARMOD, incorporating scrappage of vehicles of different vintages, changes in the size of the fleet, and resulting new vehicle sales each year) are used to model the transmission to the fleet as a whole. Modelling and measuring both stages allows estimation of the time path of the spread of the technology through the vehicle fleet.

This paper examines how these time paths look for both a past technology (seat belts) and two current technologies (electronic stability control and airbags). In addition, it shows how the techniques developed can be used to perform a policy scenario – the uptake of radical fuel efficiency improvements.

1. Modelling the uptake of technologies into the vehicle fleet

As mentioned, there are two stages to be gone through in order to understand how new technologies spread through the fleet:

1. Measuring the spread of new technologies through new vehicle sales
2. Modelling the incorporation of these new vehicles into the fleet

To measure the spread of new technologies through new vehicle sales, a dataset has been constructed by BITRE specifying incorporated technologies by make and model in the sales of each of the past 30 years (BITRE unpublished). The dataset is drawn from three sources. The Federal Chamber of Automotive Industries' VFACTS database provides data on the number of new sales by make by model by year. Glass' Guide provides data on the vehicle technologies by make by model by year. Finally, the Department of Infrastructure and Transport's Green Vehicle Guide provides data on fuel intensities (l/100km) by make by model by year.

The BITRE database can be interrogated to show trends in the characteristics of new vehicle sales. For example, BITRE (2009) sets out the trends from 1980 to 2008 in new vehicle power, weight, engine efficiency, fuel intensity and emissions intensity. But the database can also document the spread of new technologies through new vehicle sales – for example, airbags and electronic stability control. New technologies usually spread through new vehicle sales in a logistic (s-shaped) pattern. Thus, where the spread of a technology through new vehicle sales is incomplete, a rough guess can be made as to the pattern of completion.

Once the pattern of spread of a new technology through new vehicle sales has been measured, the process of modelling the incorporation of the technology into the whole fleet can begin. In Australia, that process uses the BITRE CARMOD model (BITRE 1996).

CARMOD operates in the following way.

Vehicle ownership per person is specified as following a logistic pattern, with saturation above 700 cars per thousand persons. Multiplying by the median ABS projection of the population gives the projected number of cars in the vehicle stock at any date.

Any increase between years in that desired stock (these days mostly to cater for population growth) must be met through new sales. New sales must also replace the number of vehicles scrapped during the year. The number scrapped out of each age vintage in the stock is assumed to be a constant fraction (scrappage rate) that varies (increases) with vehicle age.

The net result is that the number of new sales is the sum of scrappage and fleet expansion.

So finally, having measured and roughly projected the penetration of new technologies into new vehicle sales, and having the CARMOD model which allows tracking the incremental penetration of new vehicles into the fleet as a whole, it is possible to calculate the time path of the spread of new technologies through the vehicle fleet.

The rest of this paper examines how these time paths look for both a past technology (seat belts) and two current technologies (electronic stability control and airbags). In addition, it shows how the techniques developed can be used to perform a policy scenario – the uptake of radical fuel efficiency improvements.

2. A past technology – seat belts

To illustrate how this framework operates with a technological policy for transport, the following example is provided in relation to the spread of seat belts.

In the US, the adoption curve for the technology spread through new car sales in a fifteen year period from 1960 to 1975 (see Figure 1). Then there was a much longer adoption curve for the spread of the technology through the fleet (as older vehicles without the technology were replaced) which defined the possibilities of the technology. Finally, there was a further delayed and still not complete adoption curve for the wearing of seat belts by Americans, illustrating the impact of a major social limitation on a transport technological innovation.

The Australian experience illustrates the process of pushing the possibilities and minimizing the limitations. Australia was in the forefront of introducing seat belt technology from the mid 1950s. Then in 1965, driver seat belts were made mandatory for all new vehicles sold. As a result, Australia's adoption curve for new sales was six years advanced on the US, as was its fleet adoption curve (see Figure 2). This represents perhaps the limits of *pushing the possibilities* (speed of technological uptake). But perhaps the major advance over the US was in the actual wearing rate. Victoria was the first jurisdiction in the world to introduce mandatory seat belt wearing laws in 1970. The other Australian states followed within a few years. The end result was that Australia achieved take-off of the technology a good 15-20 years before the US. Much of this acceleration was achieved by *minimizing the limitations* (mandating social acceptance) on the uptake of the technology.

The results of pushing the possibilities and minimizing the limitations were stark. A significant reduction in fatality rates in Australia (fatalities per billion VKT) mirrored the timing and pattern of the rise in seatbelt wearing rates (see Figure 3). A reduction in US fatality rates also mirrored the timing and pattern of the rise in seat belt wearing, but the timing was 15 years later and the results achieved not as significant. Current Australian all-occupant seat belt wearing rates are about 98 per cent versus the current American rate of about 82 per cent (see Gargett 2010a).

Figure 1: US seat belt adoption curves

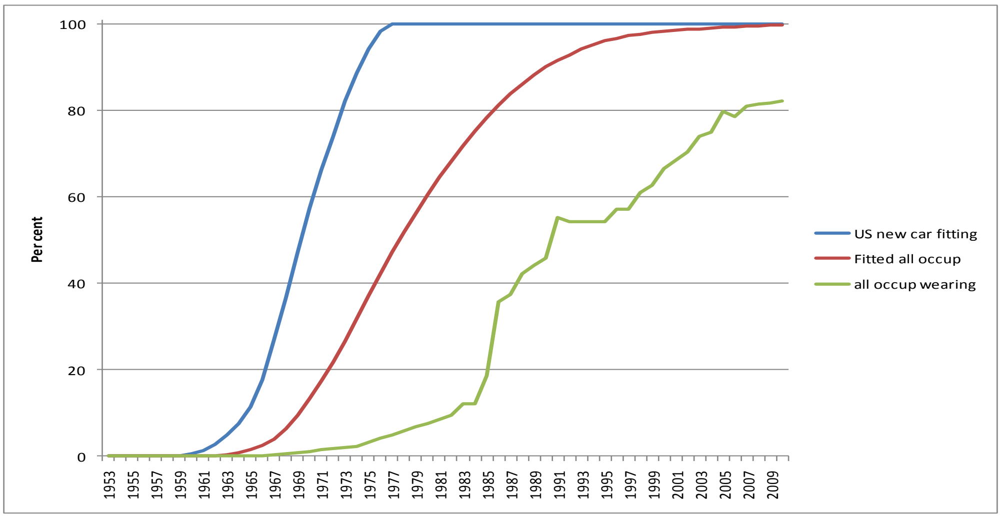


Figure 2: Australian seat belt adoption curves

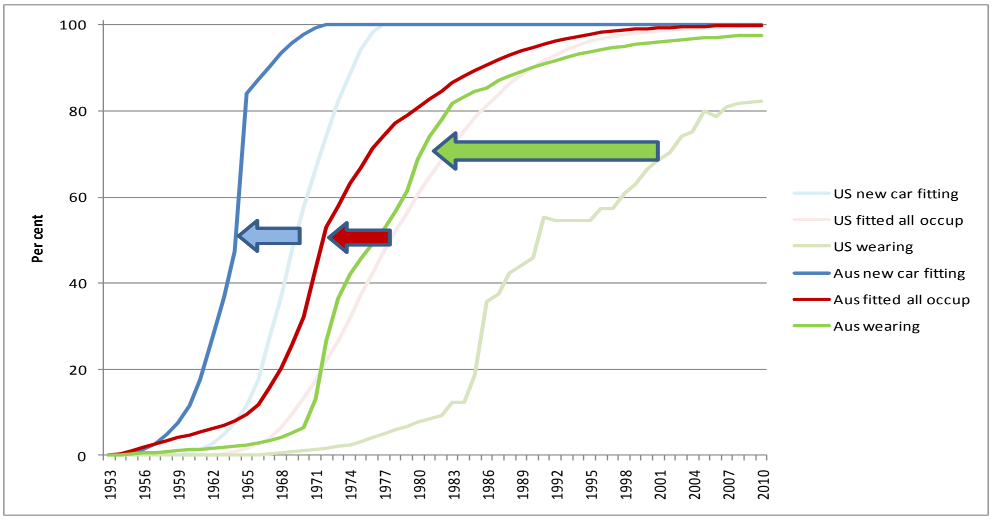
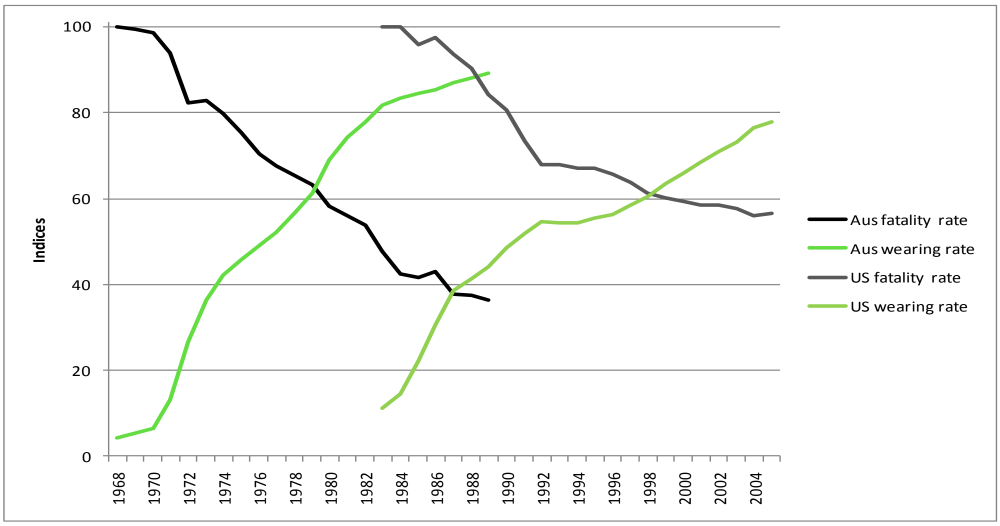


Figure 3: Seat belt wearing and road fatality rate indices, Australia and the US



Sources: Gargett (2010a), BITRE (forthcoming)

3. Present/future technologies

Two other technologies currently in the process of spreading through the light vehicle fleet are electronic stability control and airbags.

Figures 4 and 5 show that front airbags are currently installed in nearly 100 per cent of new light vehicle sales. Their take-up in new sales occupied 9 years for driver's and 14 for dual. Take-up was slower in the light commercial market (utes, panel vans, very light trucks) than in cars and sports utility vehicles (SUVs), something that is common to many technologies.

Figure 6 shows the likely path of the future spread of airbag availability through the light vehicle fleet. As with seat belts, the spread through the fleet will probably take about twice the time that the spread through new sales took. Without legislation over-ride, new sales generally take about 15 years to incorporate a new technology, versus 30 years for the fleet (time to go from zero to 90 per cent). So take-up in the fleet should be from 1993 to the early 2020s, when 90 per cent availability will be reached for airbags in the light vehicle fleet.

Figure 4: Airbag adoption curves, new cars/SUVs

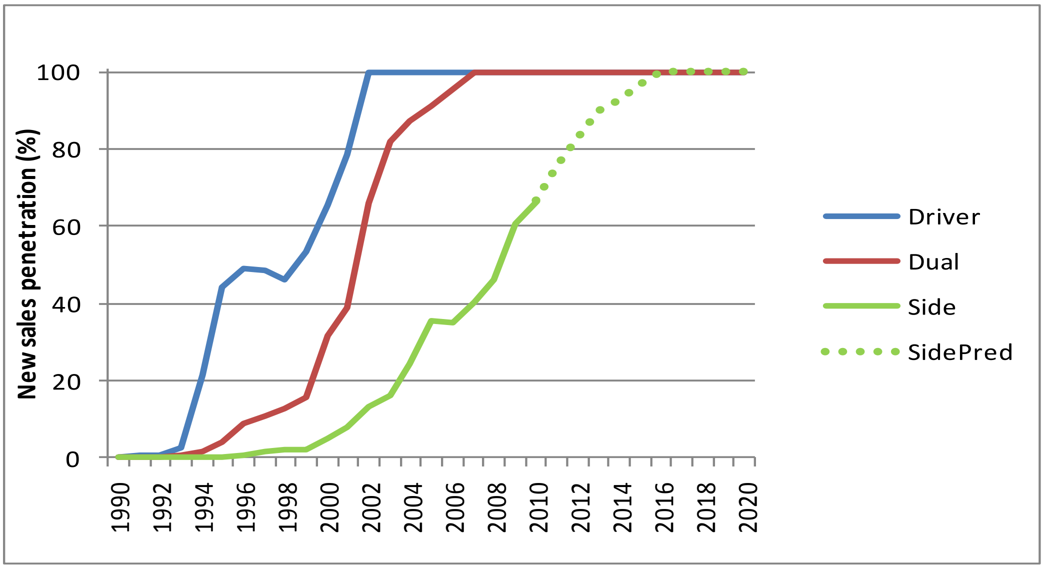
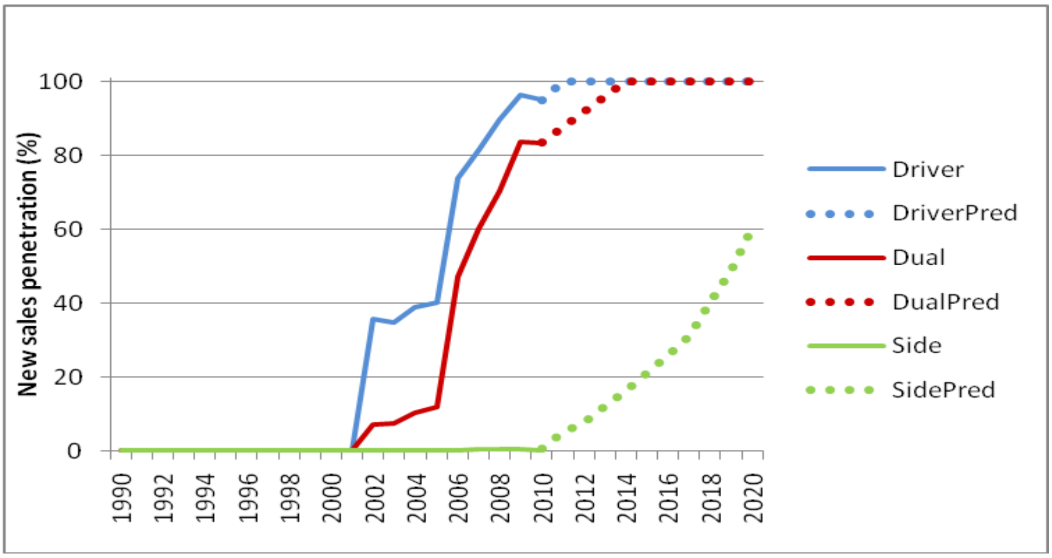
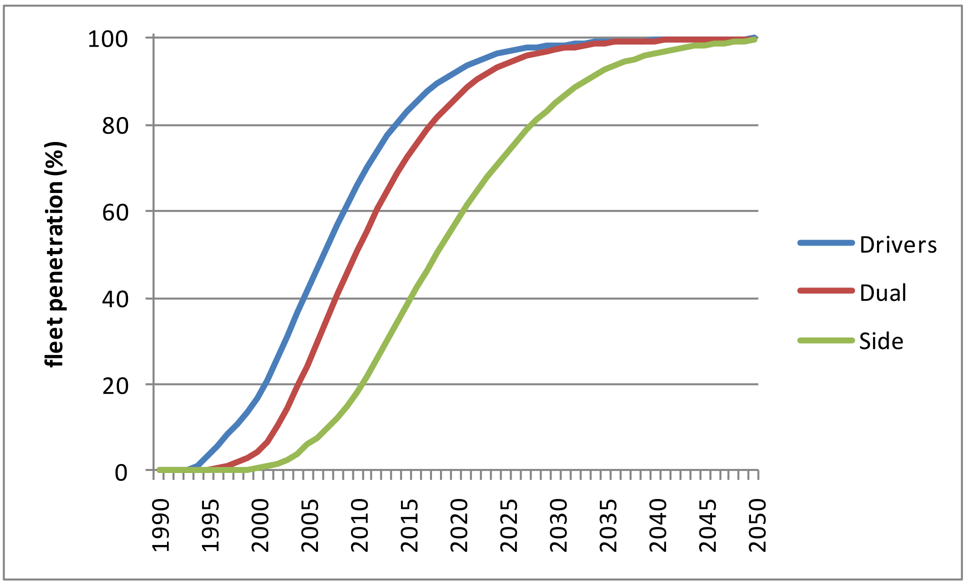


Figure 5: Airbag adoption curves, new LCVs



Sources: BITRE (unpublished)

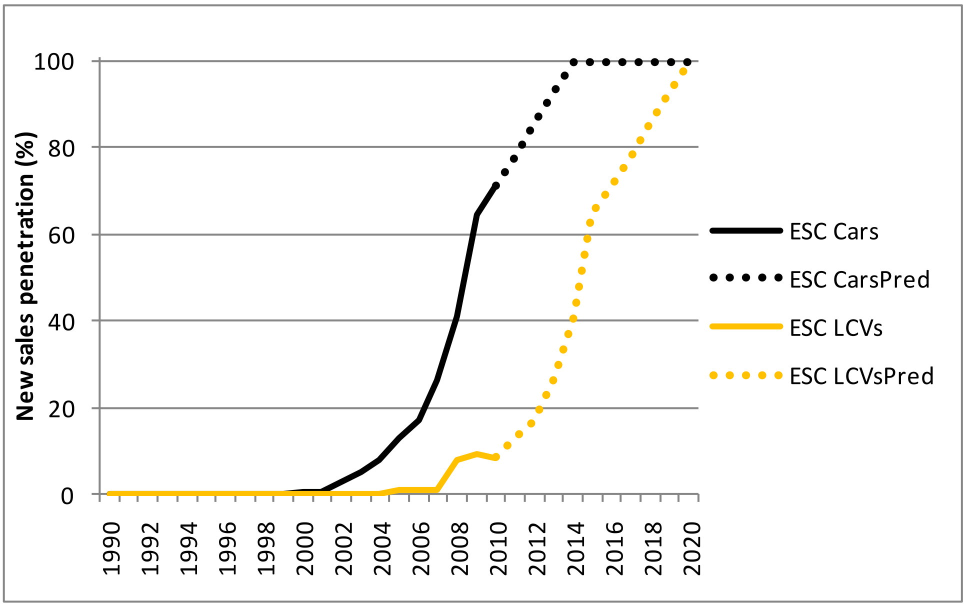
Figure 6: Airbag adoption curves, light vehicle fleet



Source: BITRE estimates

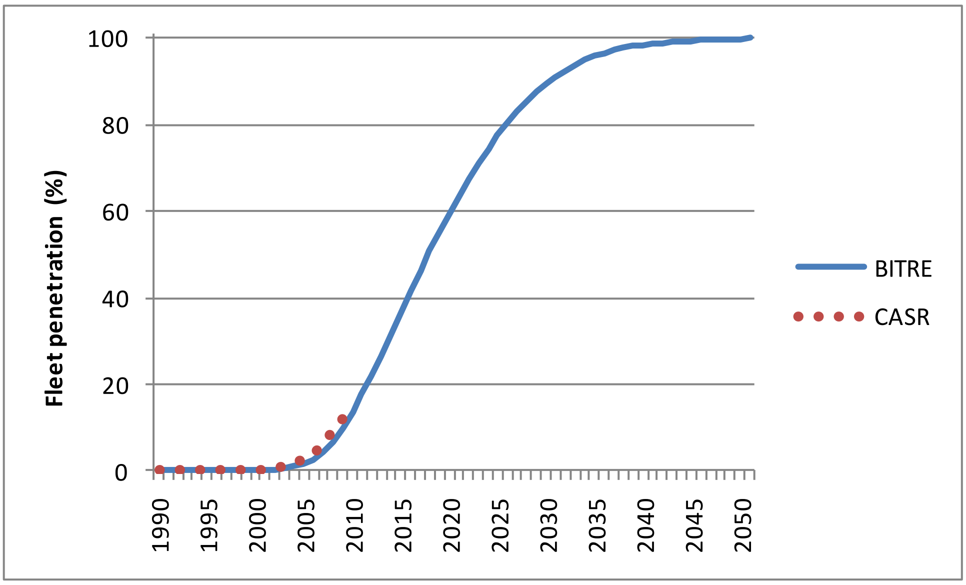
Another new technology coming on the scene is electronic stability control (ESC). It first appeared in Australian new car sales in 2002, and current legislation will see complete adoption by 2014 for new cars/SUVs (see Figure 7). Again, the spread through the fleet will take twice as long, probably reaching 90 per cent by 2030 (see figure 8). Also shown in Figure 8 is a series of measurements of ESC in the fleet using New South Wales registration statistics – see Anderson et.al. (2011). It shows that the combination of measurements of the spread though new sales (see BITRE 2009), plus the use of a fleet model such as BITRE's CARMOD (see BTCE 1996), can fairly accurately estimate levels of availability of a technology throughout the fleet over time as measured directly from registrations.

Figure 7: Electronic stability control adoption curves, new light vehicles



Source: BITRE (unpublished)

Figure 8: Electronic stability control adoption curves, light vehicle fleet



Source: BITRE estimate, Anderson et al (2011)

The point of estimating the spread of both airbag and ESC technologies through the fleet is that both are similar to seat belts in being technologies that will reduce road fatalities and injuries. For example, the Centre for Automotive Safety Research study has also shown that while increasing numbers of the fleet have ESC, these numbers are not showing up in fatal crashes. Apparently, the category of single vehicle roll-overs is the main type of accident that the technology helps avoid. As the technology spreads through the vehicle fleet, so a corresponding (although proportionally less) reduction in fatalities is to be expected.

4. Policy scenario – radical fuel intensity gains

The same conceptual framework outlined above can be used to look at what is going to be an important policy scenario – that of the possibility of radical reductions in fuel intensity of the transport fleet. Such a reduction might be crucial if some of the scenarios for higher world oil prices eventuate (see Gargett 2010b).

In the earlier technologies considered, the assumption was implicitly made that the ultimate market penetration by the new technology would be 100 per cent of new sales. With radical fuel intensity reductions, that will have to be modified.

The two technologies that comprise radical fuel intensity reductions are electric vehicles and super-efficient petroleum-fuelled vehicles.

Several electric vehicles are due to come onto the Australian market starting around 2013, for example the Nissan Leaf and the Chevrolet Volt. In addition, battery replacement stations are set to start roll-outs around the same time, for example Better Place in Canberra.

Also around the corner are super-efficient petroleum-fuelled vehicles. Volkswagen in 2011 introduced the XL-1, a super-efficient vehicle. The XL-1 weighs 795 kg (not a super light car), but it has a fuel economy of 0.9 l/100 km., with a range of 550 km. It is a diesel plug-in hybrid. It is due for limited production in 2013, with elements of the technology incorporated in other Volkswagen vehicle types.

The following discussion shows how the spread of such technologies through the fleet can be analysed. Assume the two technologies are one, with an average fuel intensity of (0.0+0.9)/2= 0.45 l/100 km. Assume that their maximum penetration of the new vehicle market will be 50 per cent by 2028 (15 years after a 2013 start). Assume the rest of the light vehicle new sales market goes from 9.1 l/100 km in 2009-10 to 7.7 l/100 km in 2015 and 6.4

l/100 km in 2024 (in line with the government's pre-election proposals). Also assume that by 2050 this segment of the market reaches 4.0 l/100 km, and traffic grows only with population growth (see BITRE forthcoming).

Under these assumptions, and assuming similar fleet to new sales adoption curve relationships as evidenced in the technologies already examined, Table 1 shows how the likely fuel intensity and fuel use of the fleet can be roughly calculated, assuming 5 per cent scrappage and 6 per cent new sales each year. Figures 7 to 9 show the results of the analysis graphically.

Table 1: The effect of radical fuel reduction technologies on the future fuel intensity and fuel use of the light vehicle fleet

	RADICAL	RADICAL	REST	REST	Light Vehicle	Light Vehicle	ABS "B"	Light Vehicle	Light Vehicle
	new sales	new sales	new sales	new sales	new sales	fleet	Population	traffic	total fuel
	Fuel Intensity	penetration	Fuel Intensity	penetration	Fuel Intensity	Fuel Intensity			
	l/100 km	per cent	l/100 km	per cent	l/100 km	l/100 km	M	B VKT	KL
2009		0	9.26	100	9.3	11.6	21.7	201	23379
2010		0	9.09	100	9.1	11.6	22.0	203	23481
2011		0	8.90	100	8.9	11.5	22.3	206	23745
2012		0	8.60	100	8.6	11.4	22.6	209	23935
2013	0.45	0	8.30	100	8.3	11.3	23.0	212	24060
2014	0.45	1	8.00	99	7.9	11.2	23.3	215	24124
2015	0.45	1	7.70	99	7.6	11.1	23.6	218	24141
2016	0.45	2	7.56	98	7.4	10.9	24.0	221	24117
2017	0.45	4	7.41	96	7.2	10.7	24.3	224	24047
2018	0.45	6	7.27	94	6.9	10.5	24.6	227	23919
2019	0.45	9	7.12	91	6.5	10.3	25.0	230	23735
2020	0.45	14	6.98	86	6.1	10.1	25.3	233	23464
2021	0.45	18	6.83	82	5.7	9.8	25.6	236	23134
2022	0.45	24	6.69	76	5.2	9.5	25.9	239	22701
2023	0.45	29	6.54	71	4.8	9.2	26.3	242	22194
2024	0.45	33	6.40	67	4.4	8.8	26.6	245	21648
2025	0.45	37	6.31	63	4.1	8.5	26.9	248	21063
2026	0.45	41	6.22	59	3.8	8.1	27.2	251	20443
2027	0.45	44	6.12	56	3.6	7.8	27.6	254	19790
2028	0.45	47	6.03	53	3.4	7.4	27.9	257	19122
2029	0.45	49	5.94	51	3.2	7.1	28.2	260	18456
2030	0.45	50	5.85	50	3.1	6.8	28.5	263	17807
2031	0.45	50	5.75	50	3.1	6.5	28.8	266	17186
2032	0.45	50	5.66	50	3.1	6.2	29.1	268	16598
2033	0.45	50	5.57	50	3.0	5.9	29.4	271	16039
2034	0.45	50	5.48	50	3.0	5.7	29.7	274	15507
2035	0.45	50	5.38	50	2.9	5.4	30.0	277	15006
2036	0.45	50	5.29	50	2.9	5.2	30.2	279	14548
2037	0.45	50	5.20	50	2.8	5.0	30.5	282	14110
2038	0.45	50	5.11	50	2.8	4.8	30.8	284	13710
2039	0.45	50	5.02	50	2.7	4.7	31.1	287	13360
2040	0.45	50	4.92	50	2.7	4.5	31.3	289	13032
2041	0.45	50	4.83	50	2.6	4.4	31.6	292	12737
2042	0.45	50	4.74	50	2.6	4.2	31.9	294	12472
2043	0.45	50	4.65	50	2.5	4.1	32.1	297	12235
2044	0.45	50	4.55	50	2.5	4.0	32.4	299	12031
2045	0.45	50	4.46	50	2.5	3.9	32.7	302	11850
2046	0.45	50	4.37	50	2.4	3.8	32.9	304	11686
2047	0.45	50	4.28	50	2.4	3.8	33.2	306	11537
2048	0.45	50	4.18	50	2.3	3.7	33.4	309	11402
2049	0.45	50	4.09	50	2.3	3.6	33.7	311	11278
2050	0.45	50	4.00	50	2.2	3.6	34.0	313	11166

Source: BITRE estimates

Figure 7: New sales penetration of super-efficient light vehicles

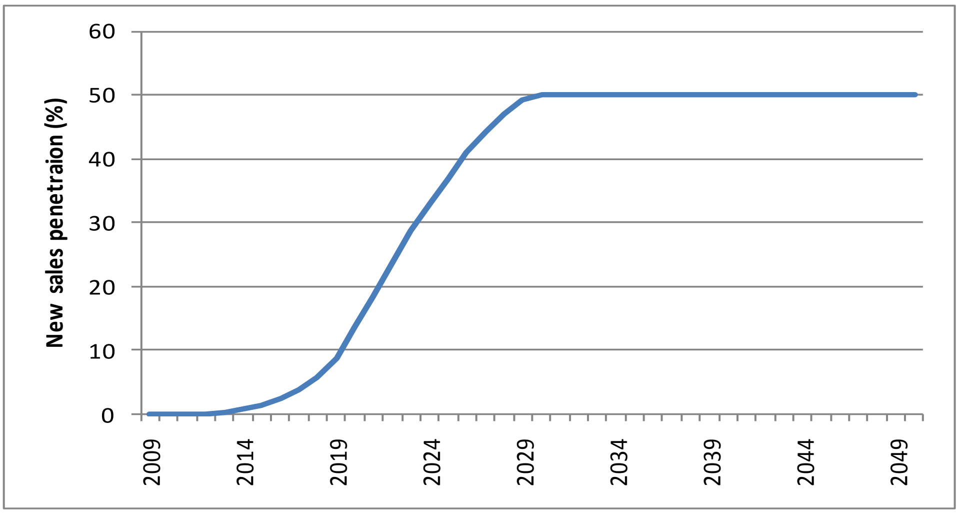


Figure 8: Fuel intensities for new light vehicles and the fleet average

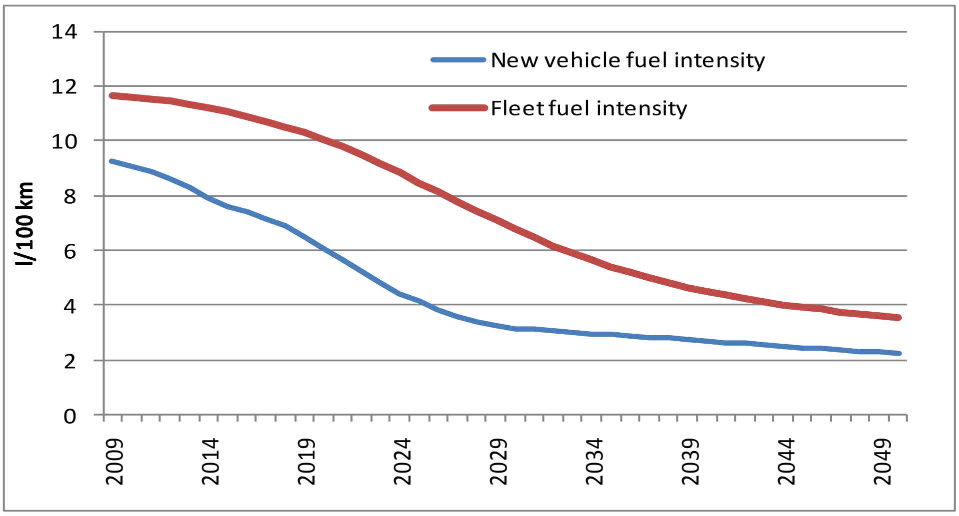
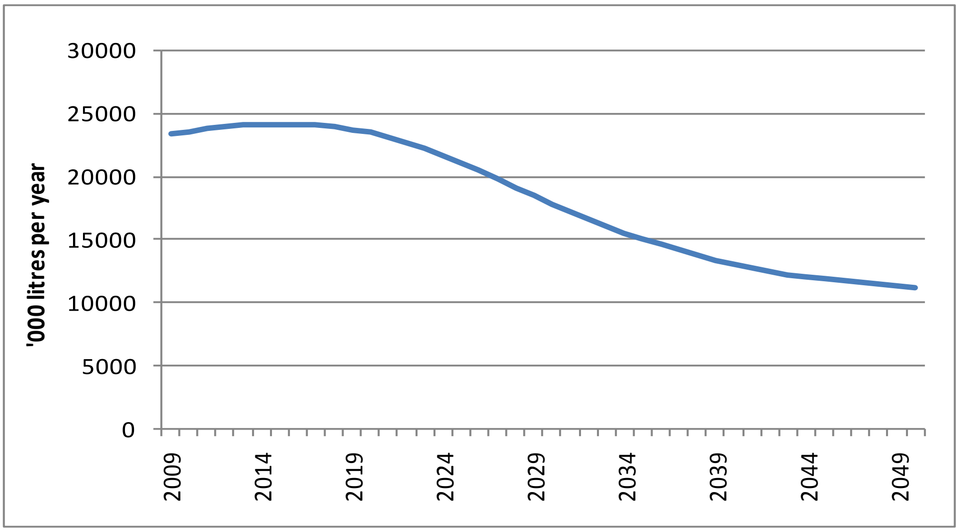


Figure 9: Resulting light vehicle fleet aggregate fuel use



Sources: BITRE estimates

Basically, under what are fairly extreme assumptions for the fuel intensity of new vehicle sales (a drop to 2.2 l/100 km in 2050 from 9.1 l/100 km in 2010), the fleet intensity drops from 11.5 in 2010 to 3.6 l/100 km in 2050. The 2050 fleet intensity is thus about 1/3 of the 2010 level. But in the meantime, traffic in 2050 has grown to be 1.5 times the 2010 level. So even extreme assumptions about fuel efficiency gains should see aggregate fuel consumption levels only drop in half (one third of 1.5). And this is in the light vehicle fleet, where possibilities of fuel efficiency gains are higher than for heavy vehicles, aircraft and ships. Thus the framework for examining technology spread helps to put some rigour and reality into the examination of this very important issue for transport.

5. Summary

New technologies are usually incorporated in *new vehicle sales* over a period of about 15 years (delayed in LCVs). The corresponding spread of the technology to 90 per cent of the light vehicle *fleet* takes another 15 years. So, all up, it takes 30 years from the first introduction of a technology to its being available in 90 per cent of the light vehicle fleet. The lags are substantial. As has been shown with seat belts, legislation can make a difference in bringing down the lags. But as has also been shown with fuel efficiency, the lags, plus off-setting traffic growth, can both operate to reduce the benefits expected from the spread of technologies through the vehicle fleet.

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