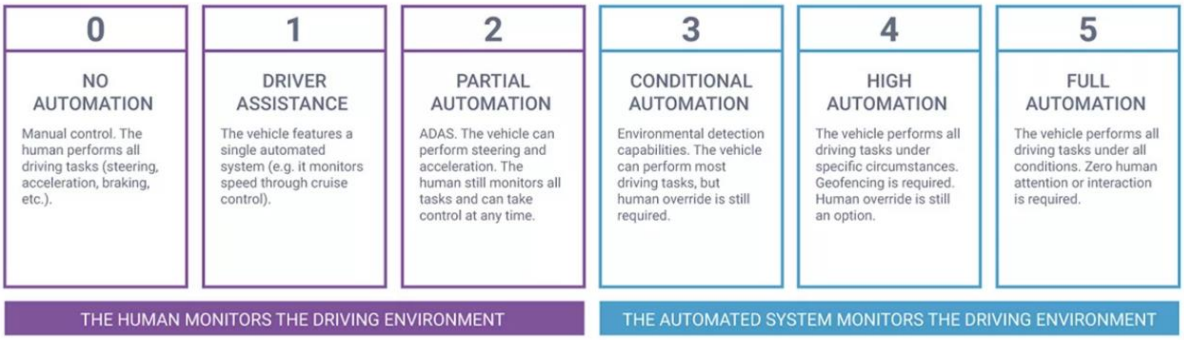
Driverless vehicle interactive scenario builder: commercial vehicles

Aims

The principal aim of this interactive scenario builder is to stimulate thoughts and ideas about the economy-wide implications of the diffusion of driverless *commercial* vehicles. By driverless, the scenario is referring to Levels 4 and 5 of automation – although, with a stretch, include Level 3[1].



It is not a forecasting tool as such, but a mechanism to investigate the possible outcomes under different conditions. It is designed to explore the broader impact on (socio-)economic shocks and the effects of policy interventions to modify the consequences of such shocks.

As a "policy maker" – at least in the context of the model – you have the ability to vary a considerable number of settings (numbers and parameter values) that, individually or in combination, have a range of socio-economic consequences.

Introduction

This webpage acts as a guide to the *Driverless vehicle interactive scenario builder*. As background, the user might find it useful to read the accompanying paper, *The diffusion of driverless vehicles: a case study* [web-link]. Always bear in mind, it relates only to commercial vehicles.

The site is not designed as a "calculator" for an individual (company) use, although it may help companies to understand both the broader economic context and the consequences of them going driverless. After all, individual companies will be taking the decision to go driverless in the context of what is happening in the economy as a whole.

The default settings provided as the starting points are based on the best data the author had to hand in 2023/4. Even official information is often somewhat dated and

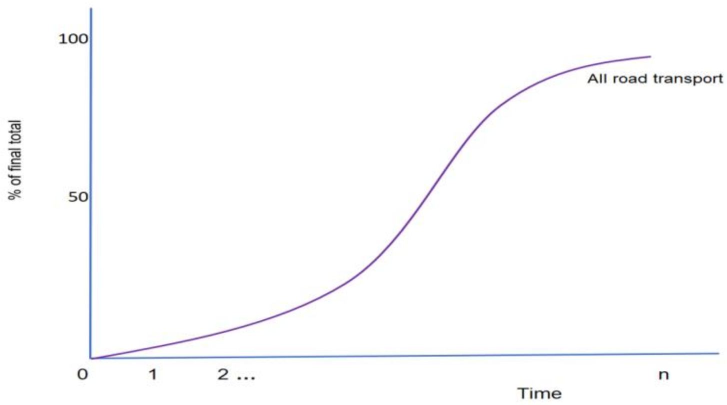
[1] https://www.synopsys.com/automotive/autonomous-driving-levels.html#:~:text=The%20Society%20of%20Automotive%20Engineers%20%28SAE%29%20defines%206,been%20adopted%20by%20the%20U.S.%20Department%20of%20Transportation.

may not apply to any individual circumstances or to some later date. Generally, you can replace the defaults with your own best-estimates.

Only what appeared to be the most important economic relationships have been included to drive the model. It may be that the dimensions that have been omitted may turn out to be more important to you as a user.

Adoption of driverless vehicles

At the economy wide-level, adoption processes – what economists term diffusion – normally take a sigmoidal (S-shaped) form, as shown below.



While diffusion in the present model is restricted to this shape for each of the four types of vehicles: Taxis (and private hire vehicles); Vans (e.g. Light goods vehicles), Buses (and coaches) and Lorries (Heavy goods vehicles).

Note that the percentage of vehicles that will eventually become driverless may not reach 100% of all vehicles. You can, based upon other knowledge set the maximum proportion to less than 100% for each type of vehicle. The value you attach to this can have major implications for all the outcomes.

The fact that the scenario builder deals with more than one vehicle type means that the composite diffusion across all types can be much more complicated, as we now explain.

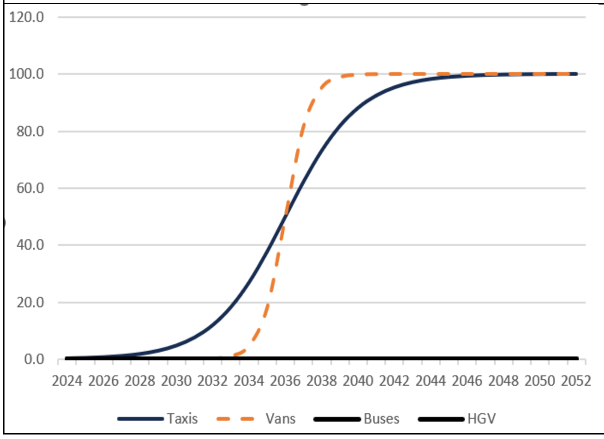
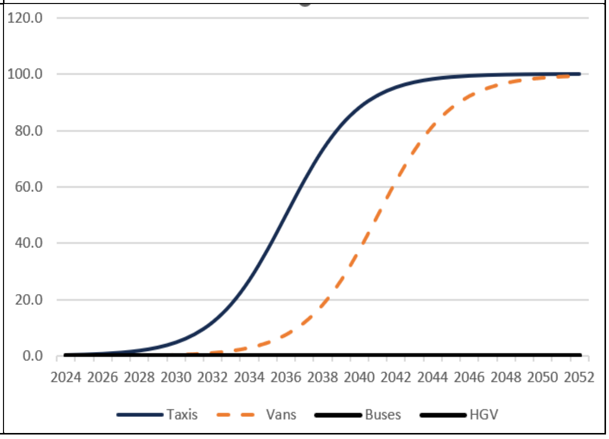
Role of the growth parameters and mid-point values

The first step in developing a scenario is to set whether you believe the rate of adoption will be fast or slow. Low values denote slow rates of adoption and high values fast rates. Higher parameter values tend to concentrate the diffusion process about the mid-point of the adoption period and lower values flatten and spread the diffusion process out. See the example S-forms in the pair of figures below.

There is no fixed growth rate for the S-shaped curve – the rate differs at every point on the curve. However, for any given growth parameter setting, it is possible to calculate the resulting highest annual rate of change in driverless vehicles (provided in the row just below the input values). This rate is crucial because excessively high annual rates of driver displacement cause additional unemployment that can be difficult, if not impossible, to cope with.

Again, as the S-curves never quite reach either zero or their maximum value (e.g. 100%), effectively they have no determinate start or end points. This is why the position of the process is determined by the mid-point of the adoption activity. In essence, the user inserts a number of years after 2024 when they believe the mid-point of the diffusion process will occur (the actual year of this mid-point is given under the input boxes).

Note that, depending on how early or late the mid-point of the diffusion process is set, growth parameter values considerably below 0.5 can cause problems, as this may make the diffusion process start earlier than 2024 or (less problematically) extend past 2052.

<table>
<tr><th colspan="2">Example diffusion curves for Taxis and Vans</th></tr>
<tr><th>Growth parameter</th><th>Mid-point of adoption process</th></tr>
<tr><td>While the use of an S-form is fixed, there are many S-shapes – determined by the <u>growth parameter</u> you choose</td><td>While the S-forms never have a start- or end-point, the year at which adoption becomes important can be determined by the adoption “<u>mid-point</u>” you choose</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

As the above figures show, the precise shape that each curve takes can differ depending on the values choosen for each of the vehicle types: taxis, vans, buses and lorries (the figure only shows two vehicle types).

Results for all vehicles as a composite of four vehicle types

The composite result for all vehicle types is the sum of the results for each four vehicle types. The following figures stack the number of Van adoptions on top of those of Taxis, then the Buses on Taxis and Vans, and so on.

The shape and level of the composite varies with the different growth rates and adoption mid-points you set. The following two examples, for example, have the same growth parameters (=1) and in (a) the same mid-points (Taxis=Vans=Buses=Lorries=10 years) and in (b) different mid-points (Taxis=5, Vans=10, Buses=15 and Lorries=20).

The starting values for these two examples are shown below:

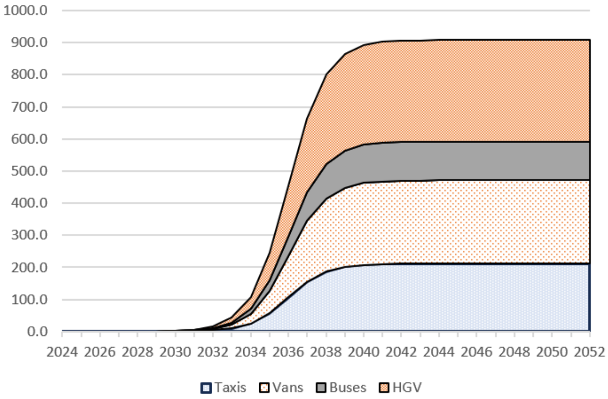
Cumulative adoption four vehicle types	
(a) Same mid-point	(b) Staggered mid-points

	(Valid growth parameters are (approx) 0.5-1.5)					(Valid growth parameters are (approx) 0.5-1.5)			
Growth parameter	1.0	1.0	1.0	1.0	Growth parameter	1.0	1.0	1.0	1.0
	(Valid mid-point ranges are (approx) 5-15 years)					(Valid mid-point ranges are (approx) 5-15 years)			
Midpoint from 2024	10	10	10	10	Midpoint from 2024	5	10	15	20

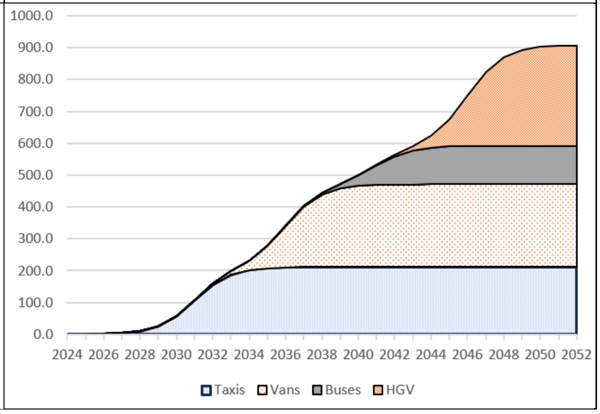
These values give the following results:

Cumulative adoption across four vehicle types

(a) Same mid-point



(b) Staggered mid-points



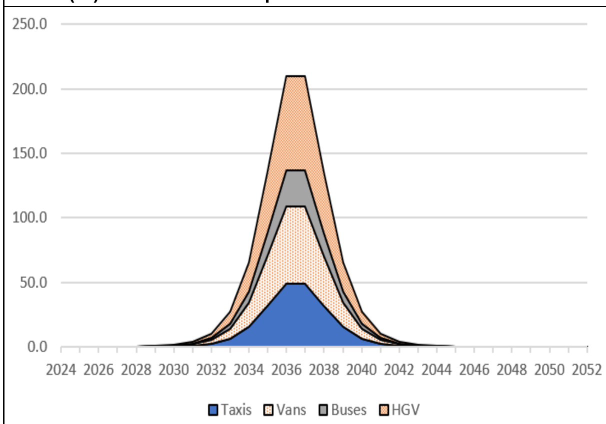
Note: Adoption does have not have to be in this order – you can make any of the vehicle types start first, second, third or fourth (depending on the values given to each mid-point).

Implications of the settings chosen for vehicle adoption

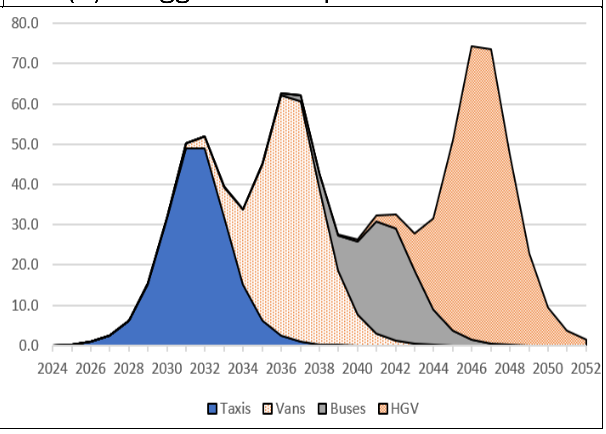
The associated annual adoption of driverless vehicles is shown below for the two cases. Given the same growth parameters and mid-points in (a), the activity is focused around 2035 and the total amount of annual activity exceeds 200 thousand vehicles per year. On the other hand, the staggered case (b) is more complex, and the greater spread of activity over a longer period reduces the highest annual change in vehicles to just over 70 thousand per annum.

Annual adoption across four vehicle types

(a) Same mid-point



(b) Staggered mid-points



The maximum annual growth rates are shown just below where you inputted the growth parameter and adoption mid-point. These are shown below:

Resulting outcomes for annual growth (same growth parameter = 1)	
(a) Same mid-points	(b) Staggered mid-points

Mid-point year	2035	2035	2035	2035	W'td av.
Maximum growth rate	23.1	23.1	23.1	23.1	23.1

Mid-point year	2030	2035	2040	2045	W'td av.
Maximum growth rate	23.1	23.1	23.1	23.1	8.2

It is important to note that, while, at the settings described above, the maximum rate of growth for each vehicle type does not change (23.1%), the all vehicle maximum rate of change falls significantly from (a) to (b).

With some experimentation, much more complex outcomes can be obtained. For, example, in the present example the growth parameters are set equal to unity for all vehicle types in both cases. However, if you set the growth parameter values differently, they have different effects, even on the annual average and the maximum annual rate of adoption outcomes.

The final two input rows allow the user to change: (i) the estimated stocks of vehicles as of (approximately) 2021/22 (thousands); and, (ii) the maximum proportion of each type of existing vehicles that will be replaced by their driverless counterparts (this maximum can take values between 0 and 100%).

The final row gives the maximum number of driverless vehicles that will eventually be adopted – a number that will change with vehicle technologies, relative prices (e.g. vehicle prices and wages), etc. (This is just the starting value x the upper adoption limit)

Employment implications of adopting driverless vehicles

Currently, there is an assumption that there is one driver per vehicle, so as a traditional vehicle is replaced with driverless, one driver loses their job. This assumption will be replaced, once we have firmed up the data about this.

This section deals with driver displacement. When displaced, drivers are assumed to flow into unemployment and increase the stock of unemployed, but then they find jobs gradually over time. The rate at which they leave unemployed – the attrition rate from unemployment – can be set.

So if 1000 drivers are made unemployed at, say, the end of 2030, an annual attrition rate of 50% would mean that 500 of them found employment by the end of 2031 (500 remained in unemployment), a further 250 found employment by the end of 2032 (so 250 remained).

The ONS figures for the proportion leaving is about 75% in the first year. For various reasons, the present scenario builder suggests this attrition rate would be significantly too high (see Box 1)

Box 1 Issues with ONS: vehicle drivers

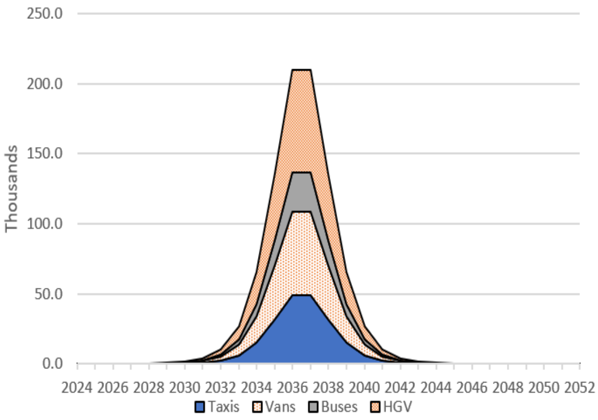
(i) these are not figures about those leaving to a new job (e.g. they may become inactive);
(ii) while the ONS overall results are not greatly different between white and all ethnic groups combined, this does not reflect particular ethnicities (e.g. Taxi drivers)
(iii) the data do not reflect the fact that the leaving rate falls:
   a. the longer the duration of unemployment
   b. the higher the overall unemployment rate
   c. the higher the unemployment rate amongst lower skilled individuals.

Further research is needed to give more precise estimates, so, in the present case, the suggested rates of moving out of unemployment would lie between an upper limit of 70% and a lower limit of 30%. The default setting is put at 50% for all four driver types.

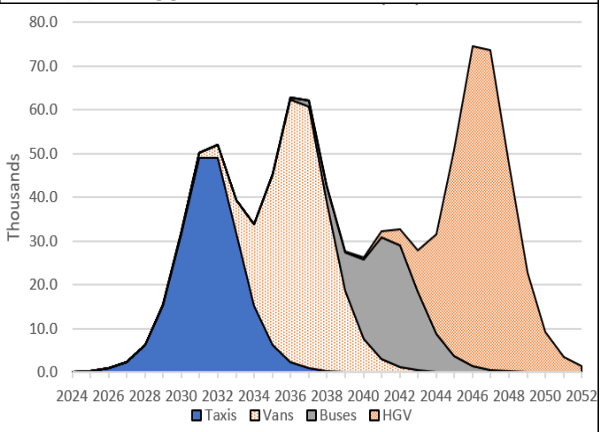
Based on the same settings as above, with a 50% attrition rate, you should expect to see the following results:

Driver inflows to unemployment each year (50% attrition rate)

(a) Same start

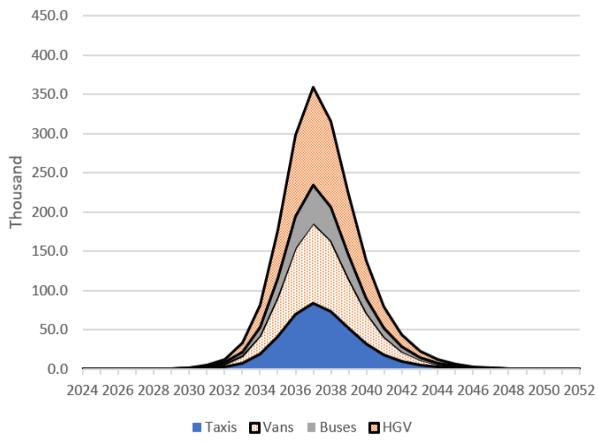


(b) Staggered starts

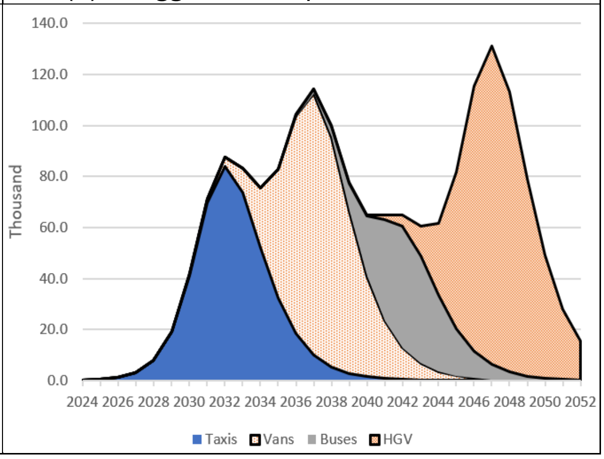


Unemployed stocks of drivers (50% attrition)

(a) Same mid-point



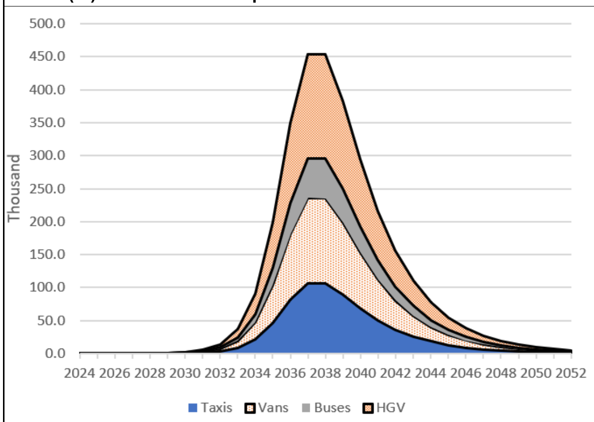
(b) Staggered mid-points



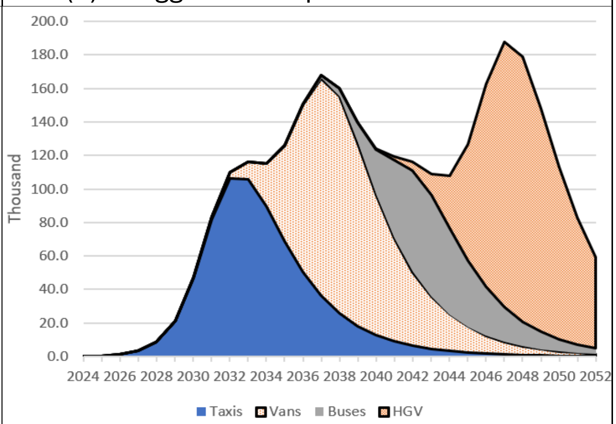
Clearly, lowering the rate of outflow from unemployment raises the stock of unemployed and raising the rate lowers the stock, as shown in the following two examples (attrition rates of 30% and 70% respectively). The annual inflow to unemployment is the same as in the previous figures.

Unemployed stocks of drivers each year (30% attrition rate)

(a) Same mid-point



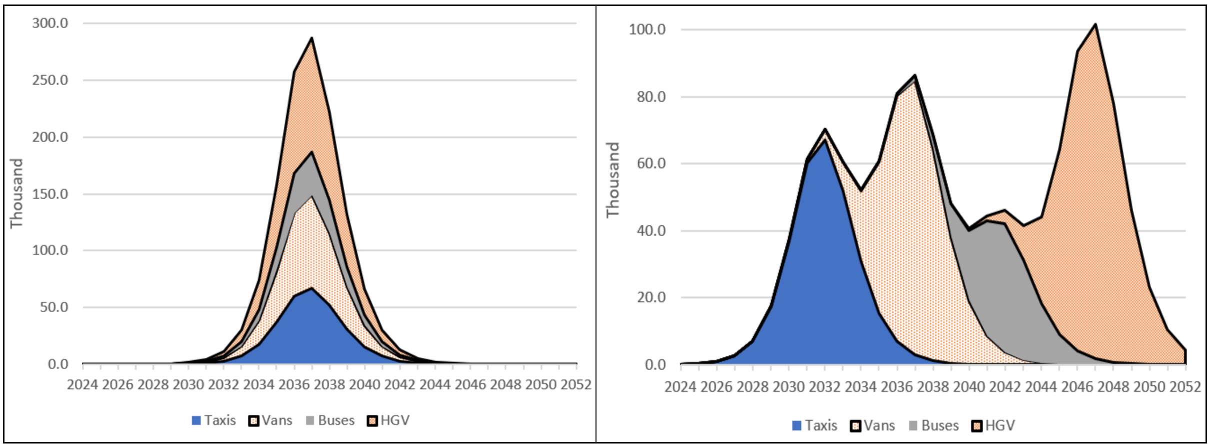
(b) Staggered mid-points



Unemployed stocks of drivers each year (70% attrition rate)

(a) Same mid-point

(b) Staggered mid-points



Financial implications of driverless vehicles

Basic financial assumptions

The additional unemployment that driverless vehicles may cause has direct financial implications for individuals and government, unless – which is highly unlikely – individuals are able to move immediately from their driving occupation to some alternative with the same (or better) pecuniary rewards as before.

The remaining examples continue with scenario (b) from above, along with the default settings for the rate of leaving unemployment.

	(Valid growth parameters are (approx) 0.5-1.5)				
	Taxis	Vans	Buses	HGVs	
Growth parameter	1.0	1.0	1.0	1.0	
	(Valid mid-point ranges are (approx) 5-15 years)				
Midpoint from 2024	5	10	15	20	
Mid-point year	2030	2035	2040	2045	Weighted average
Maximum growth rate	23.1	23.1	23.1	23.1	819.4
Starting numbers	212.0	259.0	121.0	316.0	908.0
Assumed upper limit	100.0	100.0	100.0	100.0	100.0
Maximum vehicle adoption	212.0	259.0	121.0	316.0	908.0

	(Valid rates from 0 to 1 1="best")			
	Annual attrition rate from unemployment			
	Taxis	Vans	Buses	HGVs
	0.5	0.5	0.5	0.5
% of cohort leaving p.a.	50	50	50	50

The following treatment of the individual (personal) and government consequences is simplified and depends heavily on individual pay and the tax rate. Both of these values can be set within the model.

The default values are based on the Annual Survey of Hours and Earnings set at:

	Taxis	Vans	Buses	HGVs
Salary (£000)	15.0	19.0	25.5	33.0
Tax rate %	20.0	20.0	20.0	20.0

There are numerous problems in coming up with accurate values for these, which are again discussed in the accompanying paper (REF again?). Not least of these is that ASHE only covers employees, while some vehicle types, in particular, Taxis, the majority of drivers are self-employed.

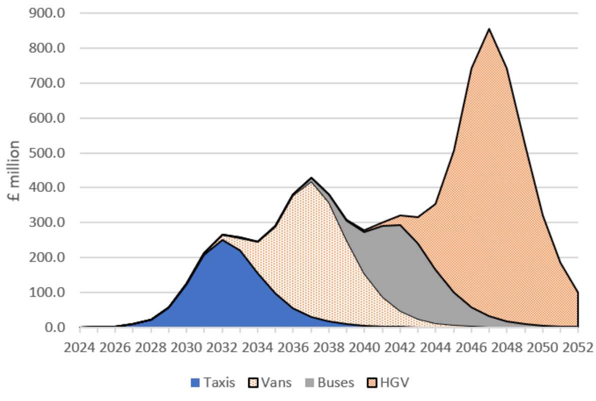
No adjustment has been made for tax allowances – again self-employment and personal vehicle ownership amongst drivers make this difficult – which would increase the personal loss and reduced the government loss. Tax rates are allowed to vary and should be input at values between 0 and 100. Given the average wages adopted as default values, basic tax rates would be 20%.

Impact on government finances

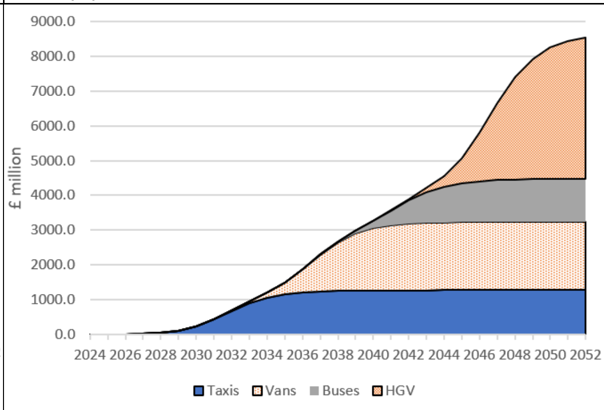
The resulting reduction in tax income for the government below are based on the default values for the average annual income of individuals and the 20% tax rate.

Tax revenue burden: tax losses and benefit, etc. costs

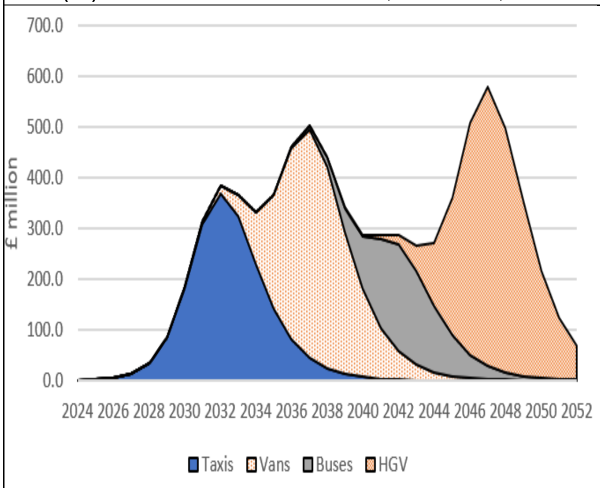
(a) Annual tax loss



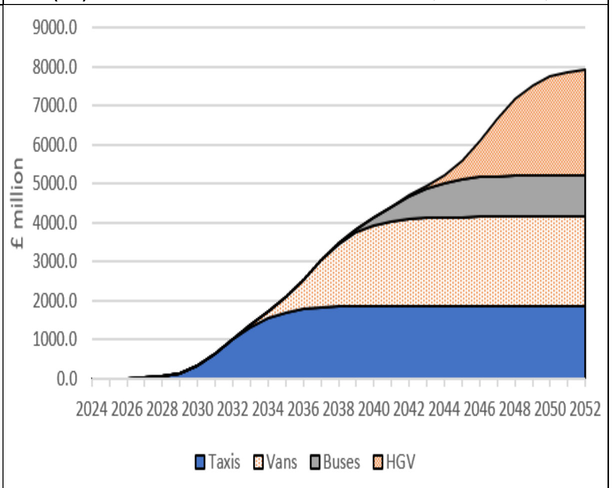
(b) Cumulative tax loss



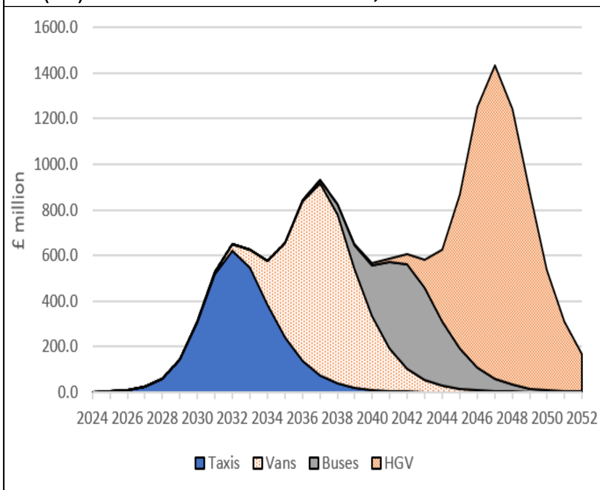
(c’) Annual revenue burden, benefits, etc.



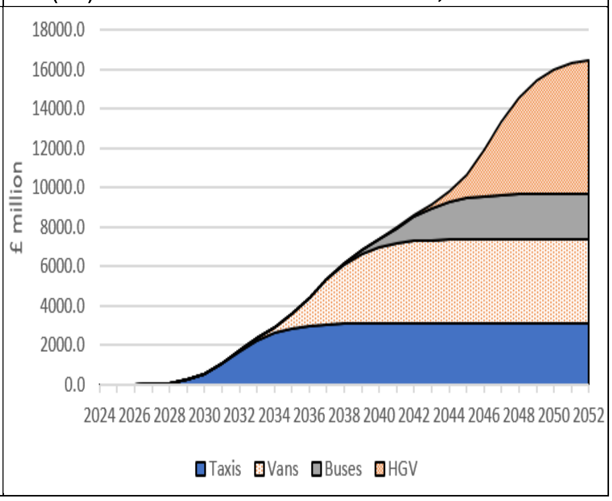
(d’) Cumulative revenue burden, benefits, etc.



(c”) Annual revenue burden, total



(d”) Cumulative revenue burden, total

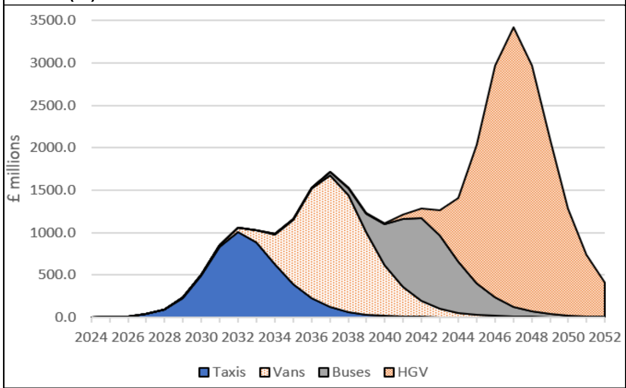
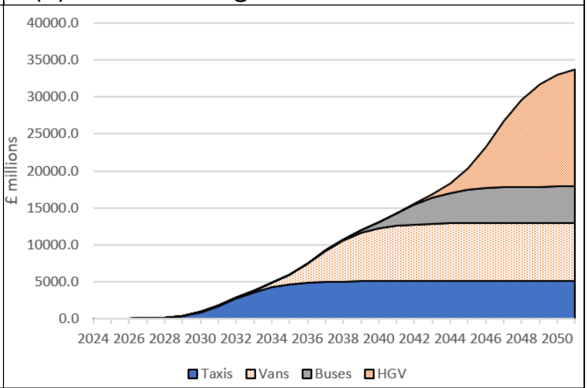
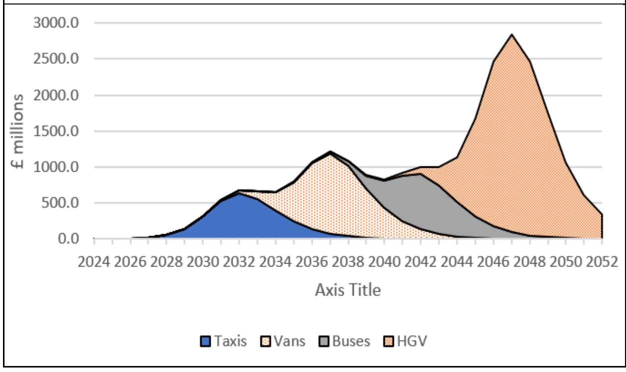
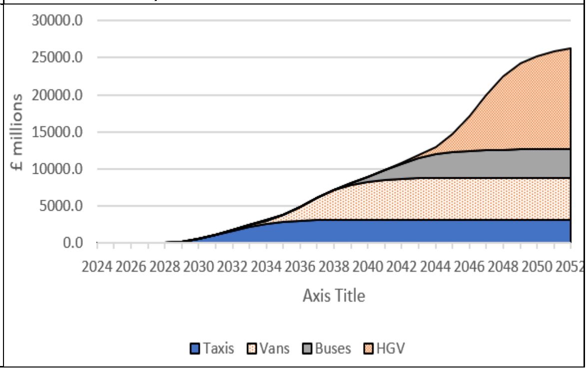


Impact on personal finances

The loss of personal income amongst displaced drivers is essentially the same as that of the loss of tax revenues to the government, but four times larger (e.g. it is 80% of the pre-tax income rather than the tax-loss equivalent of 20%). The main difference is that the payment of benefits whilst the ex-drivers are in unemployment is a further burden for the government (or more accurately for general tax-payers), but a benefit for the displaced drivers that then receive it.

This omits any discussion of non-income benefits to the unemployed, for example, in the form of retraining – which can be added into the calculation, but which is currently set to the default value of zero.

The results are generated by the model based on the data used in the previous discussion of the government finances and produces the following results (based on the default settings, with the exception of the "staggered adoption" assumption – scenario (b) throughout).

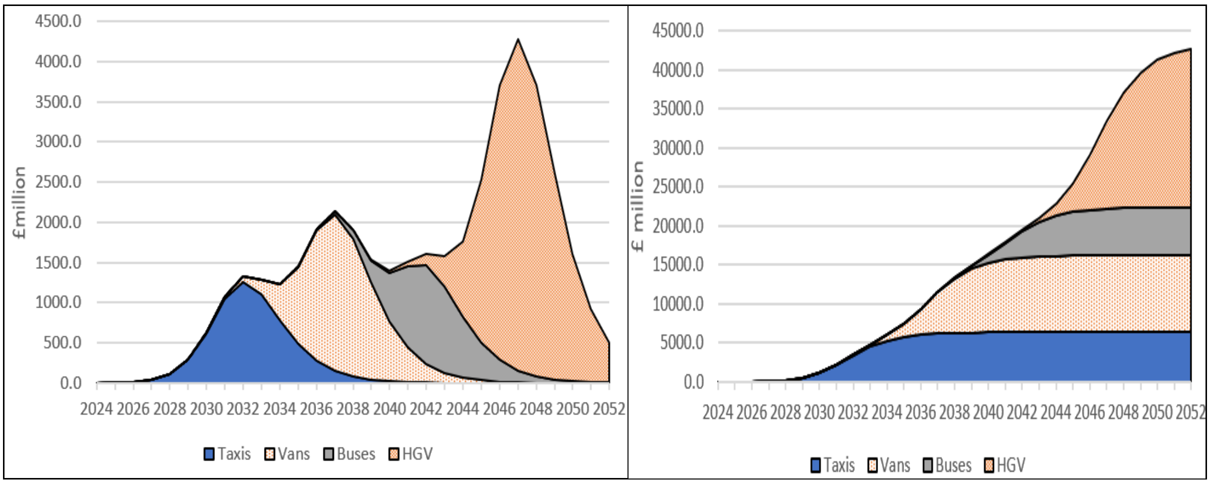
<table>
<tr><td colspan="2">Gross and net individual income loss</td></tr>
<tr><td>(a) Gross income loss</td><td>(b) Cumulative gross income loss</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>(a') Net income loss (after benefits)</td><td>(b') Cumulative net income loss (after benefits)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Societal loss

Societal income loss is the sum of the government loss and the private (individual) loss – in other words the benefit transfer that is a burden on taxes off-sets the additional income it provides to individuals (e.g. there is no gross and net). This does not need further explanation in terms of the process of deriving the graphs.

The results are shown below.

Societal income losses	
(a) Societal income loss	(b) Cumulative societal income loss



£million
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
2024 2026 2028 2030 2032 2034 2036 2038 2040 2042 2044 2046 2048 2050 2052
Taxis Vans Buses HGV
£ million
45000.0
40000.0
35000.0
30000.0
25000.0
20000.0
15000.0
10000.0
5000.0
0.0
2024 2026 2028 2030 2032 2034 2036 2038 2040 2042 2044 2046 2048 2050 2052
Taxis Vans Buses HGV