Appendix B: Mobility as a Service in the Vehicle Stock Modelling framework

Introduction

This paper sets out first of all our understanding of the requirements of a MaaS scenario, how it differs from other subsets (such as car sharing and autonomous vehicles) and, based upon evidence collated from literature, sets out suggested input assumptions for a MaaS scenario for Sweden.

This note draws heavily upon inputs prepared by Cambridge Econometrics (CE) and Element Energy (EE) for a working paper for the ECF project 'Fuelling Germany', and this draft paper should not be shared outside of the immediate project teams at CE and Viktoria.

What is Mobility as a Service (MaaS)?

The UK Transport Systems Catapult (TSC) defines MaaS as "using a digital interface to source and manage the provision of a transport related service(s) which meets the mobility requirements of a customer"[1]. More broadly, it involves a shift in the way that consumers utilise transportation, particularly in road transport; from *owners* of transportation capital (i.e. passenger cars), who use that capital to transport themselves and their friends/family, to *consumers* of transportation services (i.e. paying for the provision of a vehicle and driver on an on-demand basis, either using fixed monthly payments or one-off payments linked to individual journeys). The stricter TSC definition encompasses the linking of a number of transportation modes into a single transportation service through a digital (i.e. screen-based) portal such as a website or mobile app, where the single portal will arrange complete point-to-point transportation across different modes as required, including allowing for a single payment to be made for the entire journey.

Mobility as a Service as a term is often used interchangeably with other terms such as *Car Sharing* and *Autonomous Vehicles*. However, both of these are subsets of MaaS, rather than alternative terms for the same thing; the deployment of autonomous (or self-driving) vehicles is likely to lead to the deployment of MaaS (as the costs of being driven fall substantially if no human driver is required), but it is possible for MaaS to exist without autonomy. An application which linked (say) an Uber passenger car to a train or bus station and onward journey using public transport would be an example of a MaaS system, without any requirement that the Uber vehicle be autonomous. Similarly, car sharing, which involves methods which facilitate the shared use of a single vehicle (ranging from short-term car hire firms such as Zip Car to Uber and even traditional taxi firms) are conducive to the introduction of MaaS (as they make the provision of low-cost and convenient road transportation more straightforward), they are not required (for example in a MaaS system which utilised only public transportation).

As such, while these three systems are potentially complimentary, they are not required to co-exist within a single ecosystem. As such, in the analysis that follows we separate out the impacts on road transport into three categories, depending upon whether the effect is derived directly from MaaS, car sharing or autonomous vehicles.

The impact of MaaS on the road transportation system

A fully-fledged MaaS system could have up to three primary impacts upon the private road transportation system; however, not all variants of a MaaS system will benefit from all three, so the design of the system matters. The three are;

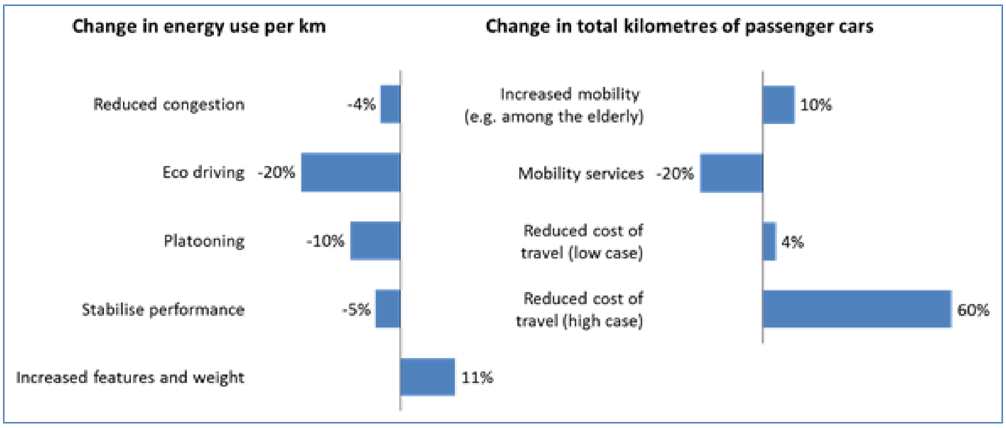
- A reduction in the number of vehicles in the stock
- A change in vehicle efficiency
- A change in total vehicle kilometres

A reduction in the number of vehicles in the stock is most directly bought about in a MaaS system which includes car sharing schemes (including short-term car hire and taxi-like services). Under such a scenario, the vehicle kilometres that were previously being demanded will still be demanded, but will be covered by a smaller number of vehicles (as each vehicle can be used by many more people).

In Germany, car sharing scheme membership reached 1 million users in 2015, and recent growth has been rapid (40-70% per annum); as such the market is expected to reach 2 million users by 2020 under current policies (or 3 million in more favourable policy conditions) [2]. It is believed that car sharing has the potential to be used by 16% of all license holders in Germany, around 6 million users in total (with penetration rates reaching up to 40% in large German cities). The number of car vehicles is required to services these users is relatively low, with TÜV estimating that 39 000 vehicles are needed to support 3 million users, a ratio of nearly 100:1. The number of private cars displaced by these car sharing vehicles depends on how many users have sold a car (or deferred a purchase), compared with switching travel modes from public transport, cycling etc. Research from fixed station car sharing schemes suggests a ratio of 5-10 vehicles displaced for each car sharing vehicle. The reduction in the vehicle fleet can therefore be calculated based on expected membership/usage of such schemes in Sweden.

A change in vehicle efficiency arises when MaaS is accompanied by the deployment of autonomous road vehicles. Autonomous vehicles can drive in a more fuel efficient manner than human drivers (reducing energy use per kilometre by 20% through eco driving and a further 5% through stabilising performance), while also benefiting from platooning (10%) and reduced congestion (4%). However, autonomous vehicles require additional hardware (and therefore weight), which increases the fuel consumption by 11%. The net effect of these is a reduction in energy use per kilometre of 27%[3] (see Figure 1). This value can be fed directly into the model as the fuel efficiency of a MaaS-enabled vehicle.

Figure 1 Expected impacts from autonomous vehicles on energy use and vehicle kilometres



All varieties of MaaS scenario are likely to lead to changes in total vehicle kilometres, since all introduce a system which reduces the cost (in terms of money and convenience/time) of transportation. This is likely to increase demand for those modes of transportation covered. However, there is substantial uncertainty around the estimated impact on total demand; principally, the extent of the rebound effect associated with lower prices; estimates range from a modest increase of 4% in vehicle km to an additional 60% (see Figure 1). In the ECF Germany study, no adjustment was made to reflect this, due to the large amount of uncertainty around these estimates (the mid-point of the two estimates of the rebound effect is a 28% increase in vehicle kilometres, but it is not clear from the underlying study whether this is also the central point of the distribution of possible outcomes or not).

Other impacts which might be considered in a MaaS scenario include impacts on the average distance driven per vehicle and the survival rates of vehicles. As set out above, MaaS schemes are likely to lead to fewer vehicles covering more vehicle kilometres, and therefore implying more kilometres travelled per vehicle. In addition, in ICE and hybrid vehicles, much of the maintenance required is due to the wearing out of parts; so it is reasonable to expect that a higher average distance travelled per year will shorten the average life of an ICE or hybrid vehicle. However, it is not clear that this is true of BEVs or FCEV vehicles, where maintenance is typically due to the age of the vehicle, rather than distance-related wear-and-tear; as such it may be that the survival rates of BEVs are not significantly affected by changes in average distance driven per year. If MaaS includes the deployment of autonomous vehicles, it is also likely that the driving software will minimise wear-and-tear on the vehicle, including substantially reducing the accident rate. In CE's previous work, the impact of adjusting survival rates has been explored through a sensitivity test, by running two alternative sets of survival rate assumptions; one which does not change the survival rates, and another which does, bringing the total kilometres driven per (average) vehicle in line with that of a current ICE car. A similar sensitivity could be explored for Sweden.

The final elements of MaaS that must be considered in the scenario are the technology costs. While there are no explicit costs associated with either car sharing or MaaS, where MaaS includes fully autonomous vehicles, there is substantial additional hardware required within the vehicle. The table below sets out the costs from two reviewed studies, and the (midpoint) estimates used in the ECF Germany study. Deployment rates for this technology should be developed as part of the scenario, although we can draw upon rates used in the ECF Germany study if required.

Study	Fully autonomous vehicle cost in 2025	Fully autonomous vehicle cost in 2030	Fully autonomous vehicle cost in 2030
IHS study (2014)	$10 000	$5 000	$3 000
Boston Consulting Group (2015)	$9 800	$4 500 (at 5% new sales share)	$2 700
Average value proposed for this study	$9 900 / €8 900	$4 750 / €4 300	$2 850 / €2 550

How MAAS is implemented in the modelling?

Before going into the impact of MAAS on the modelling, we need to talk about the assumption of how these factors are introduced in to the stock. Our assumption is that the introduction of MAAS is only achieved through new sales. The principal behind this is that current vehicle owners will not scrap there current working vehicle to switch to MAAS but would choose to adopt MAAS at the point of making a new purchase. Implicitly we are also assuming there is no policy to incentivise/force the switch such as a scrappage scheme or any kind of retrofitting/repurposing of vehicles.

Once the share of new sales that are MAAS is defined in the scenarios, these vehicles used for MAAS exhibit two main changes to their characteristics compared to a standard vehicle:

1. Sales of MAAS Vehicles is reduced as vehicles are better utilised over multiple users

2. Mileage rate are increased as vehicles are driven further as they spend less time idle

First, the sale of vehicles in the case of MAAS, for every 1 MAAS car deployed, we assume 5 regular cars are displaced in new sales as such the reduction in total sales of cars because of MAAS is:

The application of this formula can be found in Column Q of the "Autonomous Vehicle + Car Share" sheet in the VSM

This sales reduction then feeds into the modelled sales calculation reducing the number of new vehicles in the stock. The main impact of this is a reduction in the size of the vehicle fleet. In isolation, this would lead to a reduction in stock mileage and hence stock fuel consumption and therefore lower stock emissions.

The second factor of the MAAS assumptions is an increase in mileage over time. This increase in annual average mileage is defined in Column F of the "Autonomous Vehicle + Car Share" sheet. This adjustment is defined as a % increase in miles driven as such a mileage increase of 36% means that the average annual mileage of a MAAS vehicle is 36% higher than a non-MAAS vehicle of the same age.

The increase in mileage rate in isolation, lead to an increase in the total stock mileage and hence leads to an increase in stock fuel consumption and stock emission.

However, when evaluating the overall impact of MAAS, you need to consider the net impact of the two changes. Overall, the stock will be smaller but the impact on stock mileage will depend on the size of the mileage adjustment vs the reducing sales assumption. Under the current assumption in the model, we see that the reduction in sales more than offsets the increased mileage. As such, stock mileage is reduced, and stock fuel consumption fall as do stock emissions.

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[1] See https://ts.catapult.org.uk/intelligent-mobility/im-resources/maasreport/

[2] Data from TÜV Rheinland car sharing study, published in 2015. Available at http://www.tuv.com/de/deutschland/ueber_uns/presse/meldungen/newscontentde_230666.html

[3] The totals are calculated by multiplying the values in Figure 2 rather than adding, because the energy reductions from one factor decrease the impact of the other factors e.g. eco-driving benefits slightly reduce the saving from platooning because motorway driving has already become more efficient than it is today.