Predicting impacts of connected and automated vehicles

Rune Elvik, Institute of Transport Economics

The main objective of work package 3 of LEVITATE is to develop a broad set of methods for predicting the societal impacts of connected and automated vehicles. This is a multistage process, with the following main stages:

1. Identify potential impacts of connected and automated vehicles and classify these impacts
2. Define indicators for the measurement of the impacts
3. Propose methods for predicting impacts
4. Convert impacts to a common metric in terms of monetary valuations of the impacts
5. Propose methods for cost-benefit analysis of policy interventions designed to ensure that societal benefits of connected and automated vehicles are maximised.

The first two of these stages were completed in deliverable D3.1 of LEVITATE. It lists a total of 33 potential impacts of connected and automated vehicles. The impacts were classified along two dimensions:

1. Their extent in space and time
2. Whether they are intended or unintended

A distinction was made between direct impacts, which occur immediately and are noticed by each road user on each trip; systematic impacts, which are aggregate impacts occurring within the transport system; and wider impacts, which may originate within the transport system, but mainly occur outside it, in other sectors of society.

An example of a direct impact is change in travel time. An example of a systemic impact is change in the modal split of travel. An example of a wider impact is changes in land use. In general, one may view direct impacts as short term, systemic impacts as medium term and wider impacts as long term. i.e. the wider impacts will take long to manifest fully.

Several approaches to predicting the impacts of connected and automated vehicles can be found in the literature. However, the most frequently used approach is microsimulation of traffic. Usually, a real traffic system is used and a simulation model calibrated to that system, meaning that simulation accurately reproduces current traffic in the system. Then, changes in key characteristics of traffic, such as total capacity, travel time, mean speed, and traffic conflicts are estimated as a function of the market penetration rate of connected and automated vehicles. It must be admitted that analytic choices can greatly influence the results of traffic simulation. Clearly, if connected and automated vehicles are assumed to behave exactly as human drivers do, there will not be major changes in how fast traffic moves or how efficiently road capacity is utilised. In such a case, there may be fewer conflicts, i.e. near-accidents involving vehicles on collision course, but otherwise the transition to automated vehicles behaving like human drivers may not bring large benefits.

It is therefore usually assumed that connected and automated vehicles can travel at shorter headways than manually operated vehicles, will react faster, and will tolerate harder acceleration and/or deceleration. Results of simulation can vary widely, depending on the exact values assumed for key parameters like headway, reaction time, deceleration and acceleration. To predict potential impacts of connected and automated vehicles based on traffic simulation therefore involves great uncertainty.

Figure 1 shows the results of seven studies that have tried to predict the effects of vehicle automation on the number of rear-end conflicts and lane-change conflicts on motorways. All studies provided several estimates; hence there are many data points in Figure 1.

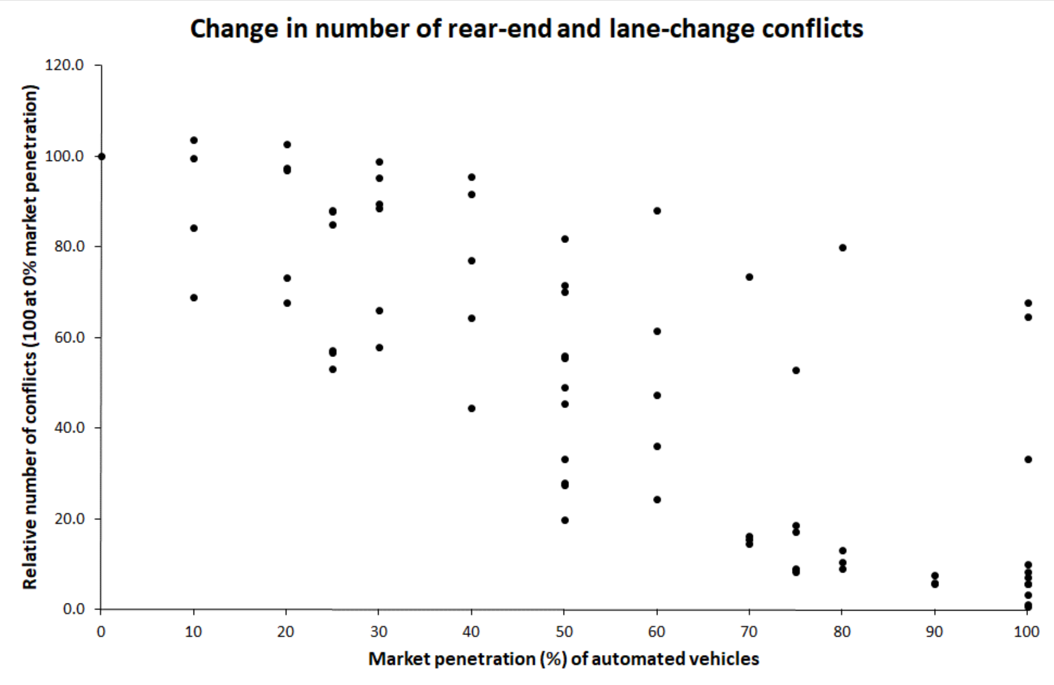

Figure 1: Changes in rear-end conflicts and lane-changes conflicts as a result of market penetration of connected and automated vehicles

The data points are widely dispersed, but consistently indicate that the number of conflicts will be reduced at high levels of market penetration of automated vehicles. There is a cluster of data points indicating that conflicts will almost be eliminated at 100% market penetration, and three data points indicating smaller reductions of the number of conflicts.

Does it make sense to try to summarise the data points in Figure 1 by fitting a function to them? In LEVITATE, the position has been taken that it makes sense to fit functions summarising data points provided that:

1. It is possible to identify a plausible functional form which passes, roughly, through the middle of the data points (i.e. has as many data points above it as below it).

2. Uncertainty can be quantified by means of functions passing through the outer data points, having the same functional form as the best fitting function.

By functional form is meant mathematical functions like linear, logarithmic, exponential, power, inverse, or polynomial. Only second-degree polynomials have been accepted as plausible. Higher-order polynomials have two or more turning points, which does not seem plausible.

Figure 2 shows functions fitted to the data points of Figure 1 based on these guidelines.

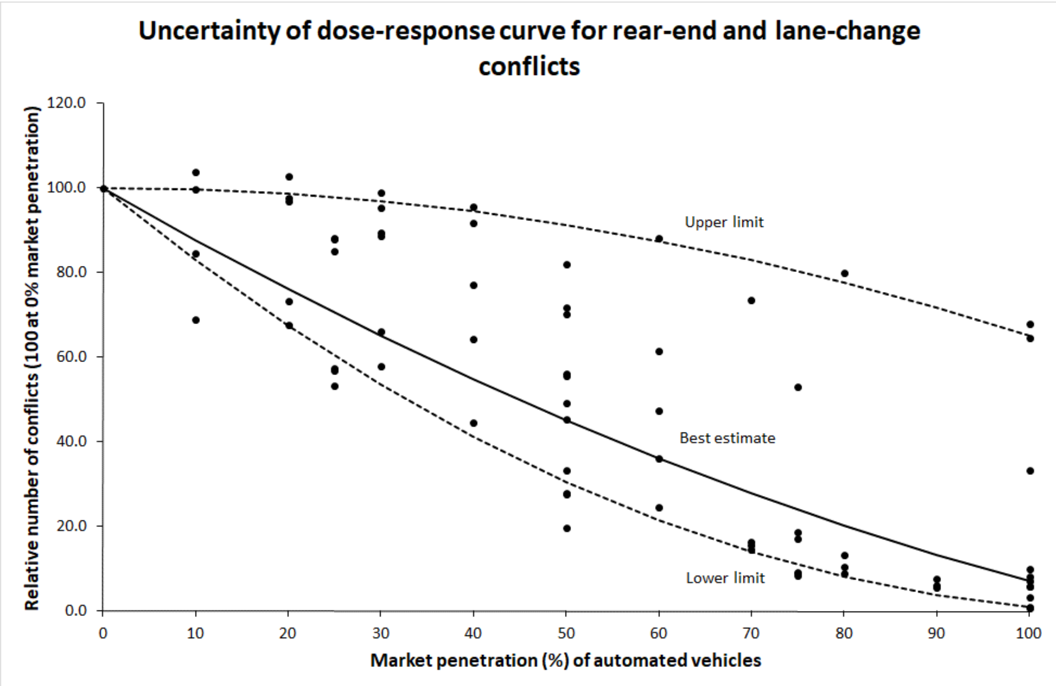

Figure 2: Functions describing the impact of increasing market penetration rate of connected and automated vehicles on rear-end and lane-change conflicts

All the functions are second degree polynomials. Most data points are contained within the area bounded by the upper and lower functions. The best fitting function does not pass exactly through the middle of the data points. It was difficult to make a function pass in the middle of the data points, as these display a highly skewed distribution. Thus, at 100% market penetration rate, there is a cluster of data points indicating a reduction of the number of conflicts of more than 90%, and three data points, located quite far from this cluster, indicating a much smaller reduction in the number of conflicts.

Despite this, Figure 2 and the functions fitted to it is informative. It shows the range of results of simulation studies, and thereby indicates how analytic choices made can influence results. At market penetration rates above 50%, there is consensus that the number of conflicts will be reduced.

Similar figures have been developed for a number of potential impacts of connected and automated vehicles, and deliverable D3.2 of LEVITATE contains a library of these functions. It effectively summarises what simulation studies have found so far.

Nevertheless, many potential impacts of connected and automated vehicles remain uncertain and very difficult to predict. In particular, the following points are important to note:

1. Traffic simulation studies have been made for urban traffic environments and motorways. Rural roads have hardly been studied, although in most countries, most vehicle kilometres of travel take place on rural, undivided two-lane roads. Potential impacts of connected and automated vehicles on this type of road are virtually unknown.
2. Some potential impacts are difficult to predict, but may to a large extent be influenced by public policy. This includes whether there will be shift to shared mobility, whether there will be changes in the modal split of travel, and whether automated vehicles will be electric or use fossil fuel.

The logical next step is therefore to develop and analyse policy options intended to ensure that the societal benefits of connected and automated vehicles are maximised. Work package 3 of LEVITATE aims to develop methods for cost-benefit analyses that may serve this end.