Robot cars in the bottleneck model: the effects on capacity, value of time and preference heterogeneity

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Extended abstract

‘Robot cars’—also referred to as self-driving or autonomous cars—are cars that drive themselves. They can drive closer together and at a more uniform speed than human driver ‘normal cars’ and thereby raise the capacity of roads. But besides this capacity effect, people who use a robot car instead of a normal car will also gain a decrease in their value of time (VOT) because the time in the car can now be spent on other activities besides driving. This will also mean that the VOT will become (more) heterogeneous (unless all drivers use a normal or robot car). Such VOT heterogeneity has important effects. To investigate the effects of robot cars, we use the bottleneck model.

In the base model, there is one VOT for normal cars and another lower VOT for robot cars. Increasing the share of users with a robot car not only raises capacity and lowers VOTs, but it also hurts users who already had a robot car because the switching users now have a lower VOT and this increases their congestion externalities (Lindsey, 2004; Van den Berg and Verhoef, 2011a). A lowered VOT means that users need a steeper travel time change over time for them to be in user equilibrium and thus they impose longer travel times on users who travel more towards the centre of the peak. Thus increasing the share with a robot car not only lowers travel cost by increasing capacity and lowering the VOT of the switching users, but also raises total bottleneck congestion cost via the heterogeneity effect (if the share gets large enough).

Robot cars lead to distributional effects, and, if the heterogeneity effect is strong enough and robot cars sufficiently more expensive to produce than a normal car, it may be socially optimal for only a fraction of users to have a robot car. Without the heterogeneity effect, it is either optimal for all users to have a robot car or none if robot cars are prohibitively expensive. When the capacity effect dominates, buying a robot imposes a positive externality, in that it lowers the cost for other users; when the heterogeneity effect dominates, it imposes or negative externality. The numerical sensitivity analyses show that the former positive externality case is most likely, but that a negative externality may occur if the effect on
capacity of robot cars is small (e.g. a 25% increase, where the literature review suggests that such a small effect may occur).

Besides socially-optimal provision of robot cars, we also study provision at marginal production cost and monopolistic provisions. Due to externality it is not (second-best) socially optimal to provide robot cars at marginal cost and typically a subsidy is needed. The monopolistic car supplier adds a mark-up to its price and tends to leads to an even larger undersupply.