Disrupting mobility

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Perspectives

Disrupting mobility

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A R T I C L E I N F O

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A B S T R A C T

Personal mobility is facing three major innovations that have disruptive potential: electrification, shared mobility and automation. In this perspective I present each of these on their own and look at their role in disrupting the auto industry, the transport system and energy system. The largest disruptive potential lies in the combination of these three innovations, i.e., in the shared autonomous electric vehicles (SAEV). While shared mobility per se might not have the potential to truly disrupt the transport system it is necessary to steer electrification and automation in a more sustainable direction. Technology and innovations alone will not be sufficient to create a new sustainable transportation system, regulations will also be necessary.

1. Introduction

The other day I attended a brainstorming lunch with researchers and experts initiated by a major bus manufacturing company. The company wanted input into the question: 'What size will future vehicles have with more autonomous vehicles on the roads?' More specifically they were interested to know if large capacity busses would still be needed, or if they had to rethink their vehicle model portfolio. The discussion clearly reflected how uncertain the future of the market and the mobility space is. Opinions and views varied and one of the experts said: 'I don't believe that people will give up private vehicle ownership'. In sharp contrast to this statement Arbib and Seba [1] predict the end of individual car ownership. Even other reports highlight that the relation to the personal vehicle may change due to innovations such as shared mobility, connectivity and automation [1–6]. No doubt it's a hot subject that engages several actors in the community ranging from car manufacturers, researchers and city planners. And the truth is that nobody really knows what the answer will be. What can be said is that there are a number of innovations that have the potential to disrupt mobility as we see it today with consequences for the transport system, energy system and city development. The trends and innovation that are highlighted are electrification, shared economy, and automation. But how disruptive are these trends and how disruptive are the implications for the transport system and the energy system?

If we look at the trends so far none of these new innovations have actually made any major dent in the personal vehicle dominated mobility. While there have been some indications during the previous years of a decline of motorization making some researchers talk about a possible 'peak-car' [7,8], more recent trends shows a 'recovery' indicating that the main cause of the decline has been economic factors [9]. Research in Sweden has even shown that attitudes towards cars and car use have not changed during the last ten years [10]. This is also shown in record high vehicle sales and the number of two-car households increasing [11]. Still there seems to be the emergence of niches, especially in major cities where membership in car sharing services is increasing [5,12], young people are taking their driving license later, and vehicle ownership is decreasing (even if in moderate numbers) [13,14].

Interestingly enough the transport sector has already experienced a disruptive change from horses to motorized transport dominated by cars. This transition went fairly rapidly. Data for the US shows that the car replaced the horse in around 12 years, even if it took 30–50 to completely phase out [15]. What is also interesting is that the motorization of the transport sector led to a growth beyond the previous usage and application areas. Cars did not only replace the typical trips carried out by horses but also enabled an increase in the overall demand for mobility and played an essential part in developing our society to what it is today [16,17]. History often has lessons to teach, still we must keep in mind that the socio-technical system surrounding the automobile today is much more complex than the one surrounding the horse 100 years ago, involving many actors in different sectors and with many vested interests [18], indicating that a transition might be harder to achieve today.

2. Interpretations of disruption

Before trying to address the question of how disruptive the innovations are I'm going to discuss the term disruption and how it can be interpreted. According to Christensen [19] disruptive technologies are those that from the start have worse performance and lower price than

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the mainstream technologies but given their convenience and with technological improvement they can take over the market. This can be seen as a disruption from below, i.e., from the lower end of the market. Arbib and Seba [1] point out that there can be disruption from above as well, i.e., technologies that are superior in performance to the main stream but are more expensive. These enter and disrupt the market through cost reductions.

Both types of disruption look at the phenomenon from a management and industry point of view. Given the role of transport in a larger socio-technical system it is interesting to look at disruption from a broader perspective and its systemic effects. It might be so that an innovation has a disruptive effect on the automotive industry but not on, e.g., the transport system. To be fair Arbib and Seba [1] look at the broader perspective as well and also emphasise the convergence of various technologies that might enable a major disruption.

In the next sections I will go through three of the major innovations that are currently being discussed when talking about future mobility: electrification, shared mobility and autonomous vehicles. For each of these I will analyze how disruptive they might be for the car manufacturers, the consumers, and the transport and energy systems. I will end by examining the disruptive potential of the combination of these three innovations. In general I will interpret the term disruptive as the ability to create a major change and interrupt the normal course of a system. For the transport system this implies a shift away from a mobility mainly based on privately owned vehicles as we have today. For the energy system it implies a major shift away from fossil fuels to more renewables but also a shift toward less centralized power production. I also want to point out that I am mainly focusing on personal mobility and not looking into freight and transportation of goods, even if there are many synergies between these and the interactions probably will increase.

3. Shared mobility

Shared mobility is a term used to describe transportation services that are shared among users. It includes a variety of options from services where the vehicle itself is shared, i.e., various forms of car sharing ranging from the traditional (or station based) to free-floating, as well as bike-sharing, to services were the ride is shared. The latter includes traditional shared modes such as public transport and taxi as well as car-pooling, ride sharing and ride hailing. There are various attempts to define all these services (see e.g. [20]) however, this is becoming more and more challenging since new services are emerging and the distinction between the services are also to a large extent blurring. For example the free-floating car sharing service ReachNow allows their vehicles to be used for ride hailing services such as Uber [21].

While some of these services are new, shared mobility is actually nothing new: car rental, taxis and public transport have been available for a long time. The public transport company in Western Sweden actually highlights this in one of their commercial ads showing that a lot of the features that are praised in the next generation of mobility, especially in autonomous vehicles, actually already exist in public transport.[1] Car sharing was first established in Switzerland in 1948 [22]. A poster from the U.S. Government aiming at saving resource during WWII reads “When you ride alone you ride with Hitler! Join a car-sharing club today!”. The difference today is that through the advance of information and communications technology, GPS and smart phones these services are much more accessible and convenient. The convergence of different technological advances has made it possible to dramatically improve existing services and offer new ones. There has also been a professionalization of the car sharing companies providing improved services and reaching a larger group than environmentally conscious consumers or those attracted to the sharing economy as a concept [23].

It’s not only technological improvements that have made car sharing services more attractive, even municipalities have played a role in creating prerequisites through e.g. favorable parking regulations [24] or as in Paris where the city council started the electric car sharing service Autolib. Municipalities can also choose not to support a specific type of service if there is a fear that the drawbacks are larger than the benefits. In San Francisco the city decided not to give preferential parking to free-floating car sharing services (i.e., a car sharing service where the vehicle can be returned anywhere within a specified area) since they thought that it might induce more vehicle use by substituting public transport and bike trips [25]. The ride hailing service Uber has been banned or partially banned in a number of cities and countries, even if the reasons have not been environmental but rather related to not complying with regulations [26].

In what way can shared mobility be disruptive? Looking at it from Christensen’s framework, they can be seen as a service that has lower costs, and lower product performance than the main stream. But can they improve and outperform the personal vehicle over time? We have already seen that there has been improvement and that the customer base is increasing beyond the early niche [5,12]. Still comparing personal vehicles and car sharing is not straightforward. If we start with costs the structure is different. In personal vehicles the upfront costs are high while the perceived running costs are lower and many vehicle owners don’t have the full cost picture in mind when they purchase a vehicle [27]. For car sharing there are only running costs and possibly a monthly fee, depending on the service’s pricing model. This can make it economically favorable for users who don’t drive on a regular basis [28], while in some cases the price structure is seen as a barrier if the vehicle is rented for a longer time [29]. Users of car sharing services often highlight the avoided costs of ownership of vehicles and an increased transparency of costs of car use as one of the advantages [30,31].

When it comes to performance it depends on what attributes are valued and how they are interpreted. The use of the term flexibility is illustrative. It can be used to highlight the advantages both of private owned vehicles and car sharing services. Normally the personal vehicle is seen as the most flexible option since it is available for the user all of the time, still flexibility is also pointed out as one of the advantages of car sharing [32–34]. In the case of car sharing the flexibility consists of a wider range of vehicle models [25], providing a fit-for-purpose mobility solution [6] and having to pay for a vehicle only when you actually need it [32].

Both costs and the term flexibility illustrate that car sharing implies a different view of mobility and what attributes are valued. A major disruption of the transport system will probably have to imply a shift in attitudes. Today the car is more than just a transport mode, it also carries a lot of symbolic value [35] such as status, political views as well as emotional values [36–38]. Bardhi and Eckhardt [32] point at the difference between ownership and access, where ownership is related more to a sense of responsibility and attachment while access is more related to a utilitarian view of the object or service. It should be pointed out that there can be a perceived sense of ownership in access and legal ownership is not necessary for psychological ownership [39]. Studies so far find that car sharing often attracts people with low sense of ownership of vehicles and a more utilitarian view of mobility [32,31,34]. While Bardhi and Eckhardt [32] don’t find that the car sharing members they’ve interviewed reject car ownership, they see that car sharing can have other signaling values such as being ‘an economically savvy and a more flexible form of consumption’.

Members that do give up a vehicle often have other reasons than just joining car sharing such a new job, a car that broke down or increase in costs related to their car such as insurance [30]. Thus it might not be car sharing alone that makes users give up the car but it facilitates the decision [31]. Other studies don’t go as deep into the perceived reasons and instead focus on quantifying the number of avoided

[1] www.futuremobility.se (Accessed 4 September 2017).

vehicles [40]. Just as important as the advantages of car sharing are the disadvantages of owning a vehicle such as finding parking, maintenance and repair. These can be enhanced through e.g. stricter parking regulations and fees. Regulating parking has become one of the tools that cities are using to try to reduce the number of vehicles and vehicle ownership [41].

To be truly disruptive shared mobility has to have the potential to grow beyond niches. Projections of their market potential show a growth potential in the near future, especially in Europe. The Center for Automotive Research sees that in Europe car sharing members can reach 10 million in 2021 compared to about 2.2 million in 2014, with a slower growth rate in the US [2]. McKinsey&Company [6] find a potential of one out of ten cars sold in 2030 to be a shared vehicle. Thus there seems to be a possibility for shared mobility to play a role in the future transport system especially in dense urban areas, but probably not to the extent of being disruptive to private vehicle dominated mobility. Their competitive advantages are also to some extent dependent on regulations from municipalities and not only on their attributes per se.

One way of improving the attractiveness of shared mobility is to combine different services creating Mobility-as-a-Service, MaaS. The term was first coined in Finland and is a bundling of services such as public transportation, car sharing, bike sharing and taxis. The idea is to offer a subscription or pay-per-use service that will cover different types of mobility needs and create a seamless intermodal travel. So far there have mainly been pilots (see Goodall et al. [42] for an overview of existing projects and pilots). It should be pointed out that the back-bone of a MaaS systems is existing public transport that would cover the bulk of the travel, even if for some of the schemes the idea is also to create a more efficient public transport system [43]. In addition, by supplying other mobility services in the same package mobility needs that can't be covered easily by public transit are provided for. This option has more potential than each shared mobility mode per se since it can provide more flexibility, fit-for-purpose mobility and increase accessibility. Will it be able to disrupt the transport system? The question is still out there and will again depend on the context. In dense urban areas it has a potential but might be harder to implement in smaller cities and rural areas.

Looking at the consequences for the energy system and transport system shared mobility is often seen as leading to fewer vehicles, fewer vehicle-kilometer-travelled per person, more efficient vehicles through a turnover rate of the fleet due to the higher utilization rate of the vehicles. I would say that the actual impact of these savings is still not really known and that there are few academic studies that assess mobility services in a stringent way. They often only study members and without a control group and thus do not take into consideration various biases in a correct way. Those few studies that take this into consideration, still find a reduction in vehicle usage but lower. Clewlow [44] finds that the reduction in vehicle ownership is dependent on the density of the area of residence of the members. Similarly Mishra et al. [45] through propensity scoring (a way of creating an artificial control group) find that car sharing members have lower vehicle ownership than non-members but the difference is lower compared to other studies. A recent report looked at ride hailing services like Uber in New York city and found that they are contributing to increased traffic and congestion [46]. There is therefore a need for better assessment of mobility services and especially MaaS as these grow to understand the implications, but also to understand how they can be designed to increase their possible benefits for the transport and energy system.

4. Electromobility

Electric vehicles (EV) are not a new technology, they have been around since the dawn of automobility. In fact in the early 20th century they were actually preferable to Internal Combustion Engine (ICE) vehicles. However, they lost the race to become the dominant vehicle, especially after the invention of the electric starter making combustion engine vehicles more user friendly. But already at that time price and range were to the competitive disadvantage of the EV. There have been several unsuccessful attempts to 'revive' EVs, but since the introduction of the Nissan Leaf in 2010 it seems like they have a chance to truly reenter the market. As of 2017 2 million EVs are rolling on the roads [47]. Scenarios point toward a steady growth with automotive companies' cumulative announcement estimated around 60 million vehicles in stock by 2025 [48].

Electric vehicles are interesting from a disruptive point of view. Christensen actually brought them up as an example in his book The Innovator's Dilemma as a possible disruptive innovation. Still when Tesla entered the market they did not follow the usual path that Christensen had pointed out, i.e., lower performing and cheaper vehicles, but rather the opposite. This has led to a discussion on whether Tesla is truly disruptive or not [49]. But if we consider disruption from above, i.e. a superior product that is more expensive and that through cost reductions can compete with the main stream market [1], then Tesla can be seen as disruptive.

EVs might be disruptive for the auto-industry but it is more questionable if they are for the transport system. An EV has the potential to be much cleaner at least considering local emissions and carbon emissions [50], but there is nothing in the EV that challenges the model of private ownership or the current transport system. While it might have attributes that are appealing to the consumer such as a silent drive, no need for refueling trips and access to more torque, it is still a vehicle and will not per se solve issues such as congestion, space for parking and safety. In the worst case reduced cost of travel (with much more efficient engines the travel cost per km can be reduced) you can have a rebound effect that worsens urban sprawl and congestion [51].

The more disruptive element of an EV is the connection to the grid. The possibility to connect an EV to the grid, often named vehicle-to-grid (V2G) can have implications to the electricity system in two different ways. It can facilitate more decentralized power generation making it easier for individual houses or small grids to be self-sufficient [52]. Arbib and Seba [1] consider the EV to be a superior product compared to an ICE vehicle partly because the battery can power an average American home when parked. It can also facilitate the introduction of renewables such as solar and wind by mitigating their intermittency [53,54]. In this case EVs are not seen as individual units but aggregated together and can function both as provider of power and storage depending on the need [55].

5. Autonomous vehicles

The advance of autonomous vehicles is happening rapidly. In 2004 DARPA (Defense Advanced Research Project Agency), organized a Grand Challenge for autonomous vehicles in the desert outside of Barstow, California. None of the 15 starting vehicles managed to finish the route [56]. Six year later, in 2010 Google announced that they had a self-driving car driving around the streets of San Francisco. Today there are self-driving features in cars out on the market such as Tesla and Volvo Cars is testing autonomous driving among 100 users in West Sweden.[2] Still it is debated when the fully automated vehicle that does not need any driver actually will be on the market. Some say that it will shortly after 2020 [1], while others question if we will ever have them [57]. The difference in opinions of the timing of the market introduction and penetration of AV depends on different views on technological development and diffusion rates, public acceptance and regulations [58].

Autonomous vehicles can be disruptive for the vehicle industry, even if all the major car manufacturers are being proactive and actually

[2] http://www.volvocars.com/intl/about/our-innovation-brands/intellisafe/autonomous-driving/drive-me (Accessed 6 September 2017).

investing in automated technology. Still there are new actors such as Tesla but even Google and Apple that are working in the field. Even if it's questionable that the latter two actually are interested in producing vehicles. It is probable that producers of larger commercial vehicles and buses are more at risk since competitors are starting to emerge, e.g., Einride, a Swedish company launching a semi-truck that can be controlled, i.e. driven, remotely [59]. New entries in the field might be more open to innovation and creative solutions while the incumbents are more vested in old ideas. For bus producers the question might be what size of vehicles will be needed and demanded in an automated future? They might have to rethink their whole production line.

For the transport and energy system the consequences can be large. Wadud et al. [60] identify that the introduction of autonomous vehicles can lead to substantial reductions in energy consumption and emissions. However, they point out that these reductions are not a direct consequence of automation per se but rather are a consequence of other related changes such as vehicle operation and design or transportation system design. They also warn that fuel consumption can increase significantly if travel costs are reduced, high speeds increased and if groups that are underserved today such as elderly and people with disabilities get access to motorized mobility. Similar results can be found in Brown et al. [61]. Even in long term scenario calculations autonomous vehicles without electrification do not cut CO_2 emissions by 2050 due to an increase in vehicle travel of 15–20% compared to a BAU scenario [51].

The nightmare scenario is when occupancy levels in vehicles are reduced since autonomous vehicles can circulate empty to avoid parking fees, drive the vehicle home again, or run errands while people are at work. It's hard today to know how completely self-driving vehicles will function in the future and what role they may have. There are plenty of speculations out there of what a vehicle might be used for, such as maybe even being the Starbucks of the future [62]. The disruptive effect autonomous vehicles can have is much larger than just the transport and energy system affecting for example land use, health and economic structure. These larger effects have still not been studied extensively, however some discussion about them can be found in Milakis et al. [63] and Burns [18].

6. Shared autonomous electric vehicles

While autonomous vehicles have the potential to lead to increased travel, vehicle usage and energy consumption they are also put forward as the opposite, i.e., as a technology that has the potential to drastically reduce the number of vehicles on the roads and create a completely new transportation system [1,51,64]. The key to achieving this is the combination of the three innovations that have been presented here, i.e. shared autonomous electric vehicles, SAEV.

Fagnant and Kockelman [65] do not presume electrification only that the autonomous vehicles are shared and find that they can reduce greenhouse gas emissions (GHG) since one SAV can replace 11 conventional vehicles. Some of the savings in Wadud et al. [60] also come from vehicles being shared. One of the major potentials for reducing energy use in Brown et al. [61] is from the enabling of electrification. Fulton et al. [51] find that combining electrification and automation of the vehicles has the potential to reduce carbon emission after 2030 despite an increase in vehicle travel due to a decarbonization of electricity production. The greatest savings in their scenarios is the combination of what they define as the 'three revolutions' with CO_2 emissions at one third of the business-as-usual scenario. In this scenario not only are there SAEV but public transport and active modes of travel such as walking and biking increase as well. In this scenario congestion and parking needs are dramatically reduced allowing for more space for the active modes.

SAEV open up for the possibility of a more efficient transport system by reducing the number of vehicles needed, at least according to simulations studies such as Martinez and Crist [64] and Spieser et al. [66]. One of the more extreme scenarios is the one presented in Arbib and Seba [1]. They predict that the automation of vehicles will make vehicle ownership obsolete mainly based on costs, leading to 70% fewer passenger cars and trucks manufactured each year. At the same time they also predict a boost in productivity and GDP due to a more efficient transport system and freeing of land (smaller roads) for other uses.

One interesting observation is that some studies [51,64] still presume or even build on the existence of a mass-transit system. If SAEV have low usage costs, mass-transit has to be even cheaper to be able to compete. However, given the lower operating cost without drivers, if subsidies are kept at the same level, it is possible that they can be free of charge for the user [1,67].

According to several studies SAEV will be lower in costs compared to vehicle ownership. For Arbib and Seba [1] the difference is so large that it outweighs all the advantages and psychological attachment to the private owned vehicle leading them to the conclusion that private vehicle ownership will become completely obsolete. So how realistic is this conclusion? The first question is how realistic it is that the cost will be much lower? Arbib and Seba [1] cost projections are very optimistic and criticized for not taking into account all cost elements [67,58]. Bösch et al. [67] point to the fact that while private owned personal vehicles will have a higher cost per mile there might be other advantages such as their ability to run errands for the owner that will make the extra cost worthwhile. Similarly as with the case of shared mobility it is a question of what attributes are valued and the view of ownership versus access [32]. Krueger et al. [68] finds that those most positive to SAEV are people that already today have a multi-modal mobility patterns and are young. Still compared to shared mobility today SAEV enhances many of the advantages and especially accessibility, making them more attractive. One possibility is that the shared mobility of today paves the way for a future with SAEV, especially if combined with regulations that limit the use of vehicles in the city center [43].

There might also be differences depending on population density and car dependency. It is for example plausible that consumers in the US will be slower to relinquish the vehicle compared to the average European. Already today we see that the market projections of shared mobility for Europe are larger than for the U.S. [2]. It is also possible that person driven vehicles won't completely disappear but will just not be used as the main mode of transport in denser urban areas. A parallel can be made to the horse, our prior main mode of transport. Horses still exist today, even if you rarely see them in city centers. Maybe manually driven cars will be owned in rural settings and used for pleasure trips.

The price of SAEV based mobility will not only depend on the cost development of technology but also regulatory costs such as taxes, congestion charging, parking and road tolls. These can be designed in a way to foster shared use of vehicles rather than single occupancy or empty vehicles. In general the role of regulation will be important in forming the future mobility system and ensuring that the technology innovations are disruptive in a way that actually reduces emissions and increases welfare.

Already today we see that municipalities can push mobility services to cleaner vehicles through regulations. Amsterdam requires free-floating car sharing services to be electrical in order to receive parking permits. Madrid allows all EVs to park for free which has also pushed the free-floating car sharing fleet to be fully electrical [69].

7. Concluding remarks

Based on current trends there doesn't seem to be an imminent disruption of mobility. The private owned vehicle is still holding its dominant position. Still there are niches for new innovations that are slowly growing and the mobility space is changing rapidly, creating an environment where a disruption actually could happen fast [19]. Shared mobility per se might not be attractive enough to truly disrupt the transportation system, but it is necessary to ensure that the other innovations, electrification and automation, disrupt in a sustainable direction. However, we can't rely on that technological innovations alone will lead to a desirable disruption from society's point of view. It is necessary to steer these to create the transportation system that society wants and that can ensure clean accessibility and mobility to its citizens.

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