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Rethinking Urban Mobility: Unlocking the Benefits of Vehicle Electrification

Hussein Dia

Introduction

As part of a more interconnected world, our cities are playing an increasingly active role in the global economy. According to the McKinsey Global Institute (Dobbs et al. 2012), just 100 cities currently account for 30% of the world's economy. New York City and London, together, represent 40% of the global market capitalisation. In 2025, 600 cities are projected to generate 58% of the global Gross Domestic Product (GDP) and accommodate 25% of the world's population. The MGI also expects that 136 new cities, driven by faster growth in GDP per capita, will make it into the top 600 by 2025, all from the developing world, 100 of them from China alone (Dobbs et al. 2012). The twenty-first century appears more likely to be dominated by these global cities, which will become the magnets of economy and engines of globalisation.

H. Dia (✉)
Swinburne University of Technology, Melbourne, VIC, Australia
e-mail: hdia@swin.edu.au

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While the forecast urban growth will be largely driven by economic development and the search for a better quality of life, the resulting success will dramatically change the scale and nature of our communities, and put a tremendous strain on the infrastructure that delivers vital services like transport and electricity (Dobbs et al. 2012). Today, more than half the world's population lives in towns and cities and the percentage is growing. By 2050, two-thirds of the world population will be living in cities and urban areas (Wilson 2012). A multitude of challenges already face our cities including congestion, emissions with ageing infrastructures in many cities at a breaking point and governments' budgets for major infrastructure projects under increasing pressure (BITRE 2015; FIA Foundation 2016; International Transport Forum 2010; WHO 2016; Wilson 2012; Winston & Mannering 2014).

Fortunately, there's been some renewed thinking in recent years about how we provide mobility and access to jobs and economic opportunities in our cities. Some of it has been a recognition that past practices have met with limited success and that new approaches are needed. And some of it is due to the widespread use of technology and innovations, and through the changing context for how we want to build future cities—smart, healthy and low carbon.

These encouraging trends recognise that the ultimate goal of mobility is to enhance access to jobs, places, services and goods. The narrative is changing, the focus has shifted from 'transport' to 'mobility', and more emphasis is given to 'accessibility'. Rather than focusing on the infrastructure we need to move people and goods around, the focus is on providing the mobility we need to access economic opportunities. And instead of giving priority to building additional infrastructure, the focus is shifting to understanding and managing the demand for travel, maximising efficiency of existing assets, and improving their reliability and resilience. These trends are also increasing the focus on the social dimensions of transport to ensure that mobility benefits are equally and fairly distributed for all income groups.

The most significant trend in recent times is the challenge to car ownership models, and in particular car sharing and ride-sharing options that have been made easier and more popular through mobile technology platforms. Still, technology and innovations continue to surprise us with their fast pace of breakthroughs and advances which continue to unfold on many fronts. There are at least six forces which will have big impacts on urban mobility over the next 5–20 years (Fig. 5.1). From self-driving vehicles and the sharing economy, through to vehicle electrification, mobile computing and blockchain technologies, each of these trends is quite significant on its own. But the convergence and the coming together of these disruptive forces is what will create real value and provide innovations. Once converged, they will enhance the travel experience for millions of people and businesses every day. These trends are increasingly pointing to a future mobility ecosystem that is electric, shared, autonomous and on-demand.

Vehicle electrification is therefore expected to have a major role in addressing our modern-day urban mobility challenges. Already, substantial progress has been achieved and the fast pace of development suggests more market disruptions will follow. In particular, the convergence of physical and digital worlds is expected to create unprecedented opportunities to address these challenges. Disruptive and emerging forces—including vehicle electrification, on-demand shared mobility, big data analytics and autonomous vehicles are expected to change the

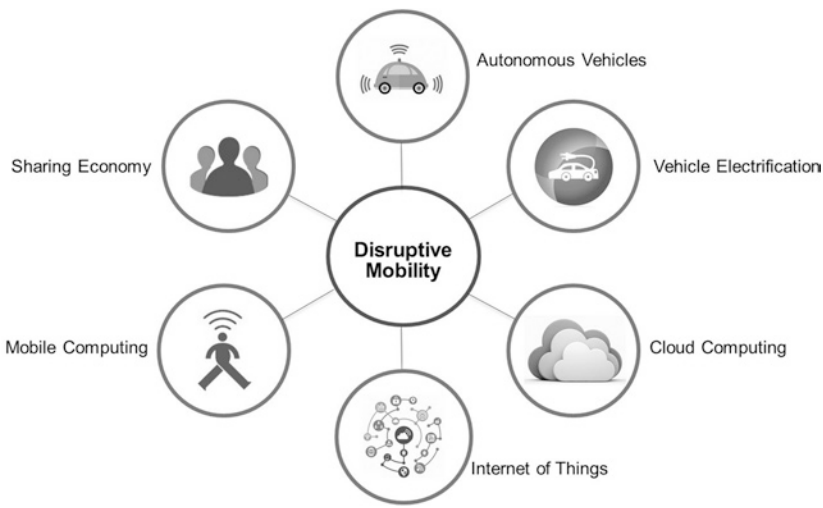

Fig. 5.1 The disruptive mobility ecosystem

mobility landscape and provide travellers with more choices to meet their travel needs while reducing reliance on building additional infrastructure. The coming together of these trends will provide new opportunities to unlock operational innovations and access to high-quality low carbon urban mobility through vehicle electrification. In addition, through data mining, artificial intelligence and predictive analytics, smart electric and connected mobility systems can help city managers monitor the performance of vital infrastructure, identify key areas where city services are lagging, and inform decision makers on how to manage city growth.

The Changing Landscape of Vehicle Electrification

Trends in vehicle electrification have gathered pace over the past few years. The on-going momentum suggests these trends will lead to an inflection point sometime in the early 2030s when it is expected around 20–30% of all vehicles sold will be electrified. This will be the result of a number of converging factors as discussed next.

Changing Consumer Attitudes

In 2016, McKinsey conducted a global online survey of EV consumer preferences which included around 3500 consumers in the US, Germany, and Norway, in addition to another survey of around 3500 consumers in China (McKinsey 2017). The survey found that around 30–45% of vehicle buyers in the US, China and Germany, would consider purchasing an electric vehicle. The survey provided some insights into the forces driving current e-mobility momentum, and how it is likely to develop in the future; the critical considerations for automakers as they create e-mobility strategies; and how automakers can set up e-readiness strategies that also avoid profitability shocks.

The survey also showed that consumer demand is starting to shift in favour of electrified vehicles and has strong disruption potential. This was demonstrated by responses from around half of consumers in the US and Germany who said they comprehend how electrified vehicles and related technology work. Also, between 30 and 45% of vehicle buyers in the US and Germany, respectively considered an EV purchase. However, less than 5% of potential buyers ultimately purchasing an EV over an ICE model (around 4% in the US, 3% in Germany, and 22% in Norway—due in part to government subsidies).

The results also showed that automakers will need greater agility to address challenges that hinder EV profitability. Although consumers were excited about EVs, they were still generally concerned about the driving range and high costs for battery packs which make the cost of offering ICE-equivalent range prohibitive. The findings also suggested that automakers may be capital constrained as they simultaneously invest across multiple mobility megatrends (autonomy, connectivity, electrification, and shared mobility). Therefore, ensuring EV profitability will be critical for automakers as they roll-out broader e-mobility strategies and new EV models to meet emission and fuel economy targets as well as consumer needs for range, convenience, and affordability.

The survey also showed that automakers can increase their EV customer base—more profitably—by offering more tailored EVs and deploying new business models. For example, in the short term, there are segments of consumers who want basic e-mobility solutions with lower range requirements. In the longer term, however, EV buyers will also look for more driving range, increased driving utility, and a broader set of capabilities and features. Automakers can potentially address a wider range of EV consumer segments by deploying new business models (e.g. car sharing and fleet operator) that take advantage of favourable EV economics.

In Australia, surveys of Victorian consumers also show they are interested in purchasing electric vehicles if more government support was available (Parliament of Victoria 2018). In 2017, the RACV undertook an 'electric vehicle consumer attitudes survey', which found over half of their respondents would consider buying an electric vehicle. The RACV reported the key findings from their consumer survey:

- More than a quarter of respondents would be willing to pay more for an electric vehicle rather than a petrol or diesel vehicle if there were more support, incentives and infrastructure in place
- More than 55% respondents thought subsidies to reduce the cost to purchase electric vehicles should be implemented by government and 53% of respondents believed government should implement subsidies to reduce the cost of installing home charging, and provide public charging infrastructure
- Around 80% of respondents considered the availability of public fast charging (i.e. 15 minutes to full charge) to be an important factor in influencing their decision to own an electric vehicle
- The RACV has also found that a significant number of Victorians believed that the development of alternative energy vehicles can provide a 'major solution to reducing the environmental impacts of motoring'.

During 2017, Eastlink also surveyed 15,000 Victorian drivers and similarly found that more than half of respondents were no longer considering a traditional internal combustion engine vehicle for their next vehicle purchase and a quarter were considering an electric vehicle as their next vehicle-of-choice.

Improved Battery Economics

Battery costs for electric vehicles have decreased substantially over the past few years (Fig. 5.2). The price of lithium-ion batteries has fallen steeply as their production scale has increased and manufacturers have developed more cost-effective methods. Recent reports (e.g. McKinsey 2017) suggest that battery costs have come down from around $1000 per kilowatt-hour (kWh) in 2010, to around $227 per kilowatt-hour in 2016 (about 80% reduction). Despite the drop, battery costs continue to make EVs more costly than comparable ICE-powered variants. Current projections put EV battery pack prices below $190/kWh by the end of the decade, and suggest the potential for pack prices to fall below $100/kWh by 2030. These estimates are for complete battery pack costs, not just battery cells.

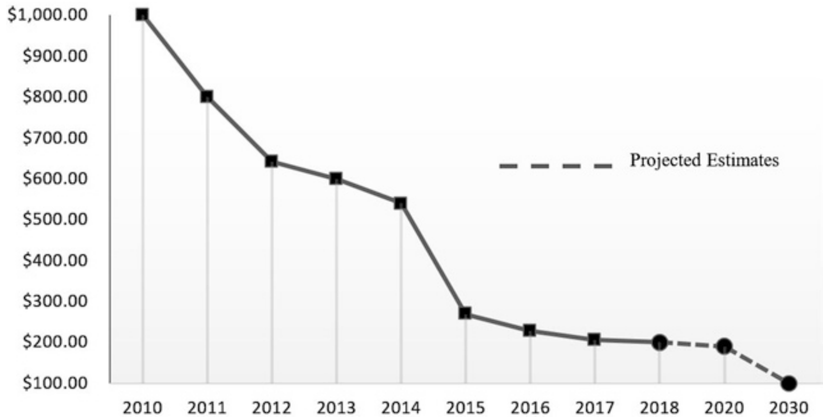

Fig. 5.2 Average battery pack cost (US$ per Kwh) (*Source* Author, drawn from data provided in McKinsey 2017)

Clearly, automakers capable of staying ahead of that cost trend will be able to achieve higher margins and possible profits on electric vehicle sales sooner. Tesla is among the automakers staying ahead of the trend. While McKinsey projects that battery pack prices will be below $190/kWh by the end of the decade, Tesla claims to be below $190/kWh since early 2016 and General Motors' 2017 Chevrolet Bolt battery pack was estimated to cost about $205 per kWh. EVs are forecast to cost the same or less than a comparable gasoline-powered vehicle when the price of battery packs falls to between $125 and 150 per kWh. Analysts have forecast that this price parity can be achieved as soon as 2020, while other studies have forecast the price of a lithium-ion battery pack to drop to as little as $73/kWh by 2030. Today, the rapid decreases in battery prices have helped accelerate EV sales, especially in Europe and China.

Broader Access to Charging Infrastructure

Investment in the supply of charging infrastructure has received considerable attention over the past few years. According to McKinsey's 2016 EV consumer survey (McKinsey 2017), consumers identified easy access to efficient charging stations as the third barrier to EV purchase, after price and driving range. Going forward, with EV prices declining and ranges expanding, the focus is increasingly shifting to overcoming the infrastructure charging barriers which is expected to gather more momentum over the next few years.

The planning and installation of adequate types of EV charging infrastructure, at accessible and widespread locations, should minimise the perceived risk of 'range anxiety'. It should also give way to increased public awareness and acceptance of EVs.

Also, understanding how drivers charge their vehicle is an important consideration in identifying the requirements of charging infrastructure. For example, drivers would normally 'fill up' their ICE vehicles on a needs basis because they can be easily refuelled at a large number of easily accessible service stations. This, however, requires a specific decision to stop whilst on-route or as in some cases, it could be the sole reason for the trip. With EVs, however, drivers might "fill up" or "top up" the battery more regularly (e.g. often to 80% unless they are preparing for a longer trip when they charge up to 100%) as opposed to waiting longer periods for 'filling up'. This provides multiple opportunities for cost-effective and convenient charging either at home, shops or at work. For longer travel, provisions need to be made such that EVs can 'fill up' at interregional fast charging stations while on-route.

This charging behaviour could in due course lead to a widespread distribution of EV charging points, with every existing accessible standard power socket becoming a potential 'topping up' location for EVs. Dedicated widespread public EV charging stations, along with a relatively smaller number of fast DC chargers, strategically located on the road network, will provide for a complete EV charging ecosystem.

According to McKinsey (2017), studies have shown that the most convenient location for EV charging is at home. Increasingly, workplaces and shopping centres are also offering charging stations as an additional benefit to employees and customers. Although a small percentage of all EV charging currently occurs at interregional fast charging locations, the McKinsey research suggests a strong psychological impact of ubiquitous public charging infrastructure on the perceived flexibility of owning an EV, and in turn, how likely a consumer is to purchase an EV (McKinsey 2017).

Stricter Regulatory Policies

A number of countries around the world are increasingly placing stringent targets on emissions reduction and fuel-economy at national, state, and city levels. The first few months of 2018 saw a number of policy-related electric vehicle announcements that sent shockwaves around the globe. China, the world's largest car market, announced it was working on a timetable to stop production and sale of internal combustion vehicles. India also declared its intention to electrify all new vehicles by 2030, with a detailed strategy of how it will carry it out (Shah 2018). The two big markets joined Britain (Condliffe 2017) and France (Chrisafis & Vaughan 2017) in making such commitments to ban the sale of petrol and diesel vehicles over the next 15 years. While these plans may not sound overly ambitious, they represent just the kinds of government policy shifts that are likely to make electric vehicles more pervasive.

In India and Western Europe, air pollution is providing a big motive to go electric. For China, the Beijing Government wants to grab a lead in the global race to develop electric vehicles, both to clean up its smog-stricken cities and position itself as a front runner in the car industry of the future. It is providing billions in incentives to automotive companies and has attracted a host of international car makers to join the local industry. In the past few months alone, a large number of vehicle manufacturers have all formed joint ventures as they try to tap into the market (Dia 2017).

These regulatory trends are reinforcing a swing towards zero-emission driving. Automakers recognise they cannot afford to be legislated out of these lucrative markets, and have followed suit with a flood of announcements where Volvo, Jaguar and Land Rover, Volkswagen, Mercedes, Audi and BMW have all now promised an onslaught on electric vehicles over the next decade (Dia 2017).

Profound Global Impacts

As mentioned before, the future of urban mobility is promising to be not only electric, but also shared, on-demand and eventually autonomous once the self-driving technologies mature and regulators allow them on our roads. This will give way to autonomous mobility-as-a-service business models where the majority of vehicles will be owned not by individuals but by mobility service providers. The world's most powerful auto companies are no longer interested in making a one-off transaction with consumers through the sale of a vehicle. Instead, they are targeting a business model in which they would offer consumers seamless mobility services in which the kilometre of travel will become the main utility. Eliminating drivers would also generate huge cost savings for transport network companies like Uber and Lyft. The mobility-as-a-service disruption will have enormous implications across the transport and oil industries and will also create trillions of dollars in new business opportunities. Vehicle manufacturers, the oil industry and governments are increasingly recognising the disruption that electro-mobility could bring about.

First, the global impact on jobs. Electric vehicles (including batteries) require less manufacturing labour than mechanical vehicles. Generally, electric engines have got about two dozen moving parts compared to hundreds of moving parts in internal combustion engines. A phaseout of combustion engines by 2030 would cost 600,000 jobs in Germany alone, according to the country's Ifo economic institute (Dia 2017). That study showed that a switch to sales of zero-emission cars would threaten 426,000 car manufacturing jobs, with the rest coming from related industries, such as suppliers. But it may not all be doom and gloom. According to the body representing Australian car parts manufacturers, the ban may be good news for suppliers to the Chinese market, like Australia, where Toyota and Holden are due to close their last plants by the end of October. The ban could boost Australian manufacturing and may even revive the local auto industry, according to the Australian Federation of Automotive Parts Manufacturers.

Second, the disruption of oil. Going all-electric by 2030 will place considerable budgetary stress on major oil-producing countries. These changes in mobility solutions and technology could end up changing the geopolitical map of the world. Stanford researchers (Arbib & Seba 2017) push the vision of an electric vehicle revolution a step further, and predict that the disruption will come earlier during the 2020s. They argue that oil demand will peak at 100 million barrels per day by 2020, dropping to 70 million barrels per day by 2030. They suggest this will have a catastrophic effect on the oil industry through price collapse, and that oil companies as well as companies throughout the oil supply chain, will have little room to manoeuvre with few strategies open to them given the speed of the changes. According to their study, the net exporter countries that will potentially be most affected include Venezuela, Nigeria, Saudi Arabia and Russia. They also explain that the geopolitics of lithium and other key mineral inputs to electric vehicles (e.g. nickel, cobalt and cadmium) are entirely different from oil politics. Lithium, which is a critical input in electric vehicles is only a material stock that is required to build the battery (unlike oil which is required to operate an internal combustion engine vehicle). In the short term, unlike oil supply, they see the geopolitics of lithium supply less critical (e.g. Jewell 2018).

Third, the impacts of electric vehicles on government coffers. By 2030, revenues from petrol taxes will be lost or reduced significantly with the shift from individual ownership of internal combustion engines to shared electric vehicle fleets. Governments whose budgets rely on this revenue could shift to road pricing and taxing of kilometres rather than fuels. Modelling by Arbib and Seba (2017) showed that $50 billion from petrol taxes will disappear from the US economy by 2030. Their modelling also showed that a 1 cent per mile tax would raise about the same revenue as petrol taxes raised today. For Australia, the revenue from fuel excise, estimated at $18.7 billion in 2017/2018, will also come under threat. Research has also shown that under future scenarios of shared autonomous mobility, the car fleet size will shrink by around 80% meaning less income from items such as vehicle registration fees and sale taxes, maintenance, insurance and parking etcetera (Dia 2017).

The industry is going to need support in its transformation and governments can do more to set the right incentives. Policies will also be needed to mitigate the adverse effects. These are discussed next.

Future Potential: Autonomous Shared Mobility on-Demand

Shared Autonomous Vehicles that are available on demand are being promoted as a sustainable solution to the urban mobility challenges such as congestion, road crashes, and air pollution (Brownell & Kornhauser 2014; Kornhauser et al. 2013). These systems are aimed at reducing car ownership rates through encouraging people to share vehicles in a similar fashion to public transport. The central premise of this idea is that deploying shared Autonomous Mobility on-Demand (AMoD) systems will translate into fewer vehicles in an urban environment. Further, it is also expected that future AVs will also be electric, which would result in less air pollution. The impacts of AMoD systems on urban and suburban environments have been evaluated in a number of simulation and modelling studies (e.g. Dia & Javanshour 2017; Javanshour, Dia & Duncan 2018). The results showed that under certain scenarios, AMoD system could result in a significant reduction in both the number of vehicles required to meet the transport needs of the community (reductions up to 88% in the size of the vehicle fleet), and the required on-street parking space (reductions up to 83%). However, the simulations also showed that this was achieved at the expense of an increase in the total Vehicle kilometres travelled (increase of up to 29%). It is important to point out that although the introduction of future electric AMoD vehicles under these scenarios is unlikely to lead to substantial reductions in Carbon Dioxide without a shift to renewable energy sources, they will contribute to an improvement in air quality in metropolitan areas particularly given the reduction in the fleet size.

Overcoming Barriers to Widespread Deployment

There are a number of actions that governments around the world can implement to demonstrate leadership and making visible and concrete commitments to the phasing out of fossil-fuelled vehicles over the next

10–15 years. For this to be effective, governments must work with the industry and vehicle manufacturers to agree on consistent timeframes.

Governments must also take steps to embed electric vehicles into all related policies including city and infrastructure planning, air quality, public health, climate change, economic development and the mix of energy sources required for future cities. Public acceptability and adoption of electric vehicles will depend to a large extent on demonstrating that governments have plans in place to ensure that electric vehicles will not rely on coal fired power generation.

Governments should also implement incentive schemes to reward the manufacture and purchase of electric vehicles. These incentives can have a big impact on the cost and convenience of switching to an electric vehicle. Governments should also consider, at a future date, adopting a road pricing scheme such as charging per kilometre of travel or congestion charging for Central Business District areas (electric vehicles would be exempt from such a charge). This will help in raising the needed revenues instead of petrol taxes, registration fees and other charges that are not related to the amount of travel.

It is also recommended that future autonomous and electric vehicle usage be a prime consideration in all future infrastructure investment. Strategies need to be put in place to encourage adoption and remove barriers to the roll-out of future fleets of electric shared autonomous vehicles.

Summary and Conclusions

Currently, the high upfront cost of electric vehicles, compared to similar ICE vehicles, makes them prohibitively expensive for many consumers around the world. However, with battery pack prices becoming more affordable, it is expected that the market uptake of electric vehicles will increase over the next 5–10 years. This will be expedited by a number of converging factors including increasing consumer sentiment and support for vehicle electrification and also tighter regulations around emissions and the lower cost production and sale of ICE vehicles.

The vehicle electrification impacts will extend well beyond vehicle manufacturing and production. The sheer breadth of the potential disruption makes it hard to predict what will happen, especially when the mix of sharing, electric and self-driving technologies all converge to disrupt the mobility ecosystem through mobility-as-a-service business models. Auto manufacturers, governments and the oil industry will have to make some tough decisions and prepare for the transformation. The industry is also going to need support during the transition, and governments will need to do more to set the right policies and where necessary, incentives. The electricity grid will also need to adapt for the increased uptake of vehicle electrification, including diversification of energy sources and renewables. While increasing the number of electric vehicles is unlikely to lead to substantial reductions in Carbon Dioxide without a shift to renewable energy sources, they will contribute to an improvement in air quality in metropolitan areas particularly if supported by policies that prioritise investment in more intensive urban development; transit-oriented and pedestrian-oriented developments; public transport and active travel options. If well planned, they will collectively lead to safer and more sustainable transport provisions while reducing motor vehicle dependence.

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