Urban Mobility: System Upgrade

Participating Partners: Michelin, Nissan

27 October 2014
Urban Mobility: System Upgrade

Urban population: 1950, 1990, 2025
Urbanisation

+117% to +233%

Increase in global vehicle kilometres travelled from 2010 to 2050. A majority of this growth will be concentrated in developing country cities and cars will account for approximately 80% of the total.

Cities are hugely popular. Covering 5% of the world’s land surface, but concentrating more than half of the world’s population, 70% of global wealth production and an almost equal share of greenhouse gas emissions, cities concentrate access and opportunity.

Cities all over the world will grow but that growth is expected to be strongest in what are now considered emerging economies. This growth will both accompany and spur economic growth which will, in turn, generate new demand for travel or change existing travel patterns. If left unmanaged, there is a real risk that this travel may erode some of the principal benefits that cities provide, namely access to people, jobs or opportunities.

Many of the new trips that will take place in the cities of the 21st century will continue to be made by foot or by public transport but if the past is any guide for the future, a very significant share of this growth will be met by privately owned two-wheelers and cars. Managing cars in cities - this is the crux of the transport conundrum faced by municipal authorities worldwide.
Urban Mobility: System Upgrade

What we did

Why

What we found
A typical car lies unused for approximately 23 hours a day. This represents a tremendous investment in overcapacity – both for car owners and for the public authorities that provide and maintain public infrastructure.

Over-capacity is not confined to cars – there are many other private goods that remain un-used most of the time; secondary homes, office space, WiFi bandwidth, etc. This unused potential is at the heart of the emerging “shared economy” which uses network technologies to enable individuals or companies to monetise the spare capacity inherent in many material goods – like cars.

Car-sharing and ride-sharing have gained ground in recent years, especially in urban areas, and have seen a tremendous influx of new, sometimes well-capitalised entrants. With more than 2 million users worldwide, car- and ride-sharing are still marginal but the arrival of major car manufacturers in the market and the rapid growth of new service providers signals the growing importance of these services in urban areas.
self-driving
Alongside rapid urbanisation and the emergence of the "shared economy" is the rapid development of semi-autonomous and ultimately self-driving capacity in cars. Already today, car systems can facilitate the driving task for humans in all contexts and can take over all driving tasks in some limited contexts (adaptive cruise control with lane assist and self-parking capacity).

The move to full autonomous driving capacity represents a major and potentially disruptive milestone that many manufacturers and system operators expect in the next few years. There are of course many technical and regulatory barriers that must be satisfactorily addressed in order to ensure that such systems provide a high level of safety but there seems to be a shared view that cars (and other road vehicles) will ultimately be able to largely operate on their own in most contexts.

What is less clear is if the existing manufacturer-car owner business model will remain unchanged with the arrival of such a technology. It is plausible that autonomous cars will be used very differently to today's cars. In particular, self-driving may enable cars to be shared amongst friends or clients of paid car-sharing networks.
Passenger pick-ups and drop-offs
We developed an agent-based model that simulates the daily travel for a hypothetical shared mobility system in a medium-sized European city. It provides a point-in-time "snapshot" of the putative future system but does not model the transition to that system.

The simulation was carried out on a representation of the street network of an actual city. It used origin and destination data derived from a fine-grained database of trips on the basis of that city’s detailed travel survey. Trips were allocated to different modes (walking, shared self-driving vehicles or high capacity public transport) on the basis of plausible but conservative rules.

In order to perform a detailed analysis, the city was divided into a homogeneous grid of 200mx200m cells, in which all potential origin and destination coordinates were assigned. In the simulation, trip requests were sent to a central dispatching system on the basis of “real” points of origins, destinations and departure times. In the ride-sharing scenarios modelled, the dispatcher also allocated cars according to their occupancy rates and the co-location of other serviceable trip requests.

The model does not include a dynamic traffic element but since road usage drops on most links and at most times in the simulation, this is not a significant constraint. Routing optimisation was made on the basis of shortest travel times accounting for the topological structure of the street network, street capacity and rules of circulation (e.g. legal speeds, one-way streets, pedestrianised areas, etc.).
Urban Mobility: System Upgrade

What we did

WHAT WE FOUND

Why

What we did

Why
We modeled two different self-driving vehicle concepts – “TaxiBots” which are shared simultaneously by several passengers, while “AutoVots” pick-up and drop-off single passengers sequentially. We looked at two different time periods (24 hr. average and peak-hour only), and modelled scenarios with and without public transport (in the form a high-capacity metro). We looked at scenarios mixing TaxiBots and AutoVots and we also looked at scenarios mixing TaxiBots with conventional cars – again in the presence or not of public transport. We report impacts on car numbers, volume of travel, congestion and use of space.

We assumed that all trips currently taken by bus are assigned to shared cars whereas all trips that could be easily serviced by high-capacity public transport, were modelled as such. Trips below 1 km were assigned to walking. We did not model cycling in our simulation, principally because cycling rates were quite low in the baseline city. We did some sensitivity testing relating to city size and density but since all trips were routed on a real street network, the results were highly dependent on the existing street structure.

Crucially, we set the constraint that all shared mobility trips should not take more than 5 minutes longer than the original conventional car trip for all scenarios.
Urban Mobility: System Upgrade

Scenario: 24 hours

- TaxiBots
  - Ride-sharing
- Public transport
  - (high capacity)

24hrs peak hrs

Number of vehicles required to provide the same trips as before: 10%
If there is one lesson to retain from this exercise it is that shared self-driving fleets can deliver the same mobility as today with many fewer cars.

TaxiBots combined with High Capacity (HC) public transport could remove 9 out of every 10 cars in the city. Whereas even in the scenario that least reduces the number of cars (AutoVots without public transport), nearly half of all cars could be removed without impacting the level of service.

TaxiBots replace more cars than AutoVots since the latter require more vehicles and much more re-positioning travel to deliver the same level of service.

Without HC public transport, 18% more TaxiBots and 26% more AutoVots are required to deliver the same level of mobility as today. However, in the TaxiBot scenario, this translates into only 5 000 additional cars that would completely compensate for the absence of HC public transport. This figure is higher, 12 000, in the case of an AutoVot system.
**TaxiBots and AutoVots will travel more than today’s cars**

+6% more kilometres travelled due to transfers from buses, pick-ups, drop-offs and repositioning

+44% more kilometres travelled due to transfers from buses and re-positioning
**Volume of car travel**

<table>
<thead>
<tr>
<th>Scenario – 24 hours</th>
<th>Car-kms (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (% of baseline car-kms)</td>
<td>3.8</td>
</tr>
<tr>
<td>TaxiBot Ride-sharing</td>
<td></td>
</tr>
<tr>
<td>No high capacity public transport</td>
<td>4.62</td>
</tr>
<tr>
<td>(commuter rail, subway, BRT, LRT)</td>
<td>122.4%</td>
</tr>
<tr>
<td>High capacity transport</td>
<td>4.01</td>
</tr>
<tr>
<td>(commuter rail, subway, BRT, LRT)</td>
<td>106.4%</td>
</tr>
<tr>
<td>AutoVot Car-sharing</td>
<td></td>
</tr>
<tr>
<td>No high capacity public transport</td>
<td>7.15</td>
</tr>
<tr>
<td>(commuter rail, subway, BRT, LRT)</td>
<td>189.4%</td>
</tr>
<tr>
<td>High capacity transport</td>
<td>5.44</td>
</tr>
<tr>
<td>(commuter rail, subway, BRT, LRT)</td>
<td>144.3%</td>
</tr>
</tbody>
</table>

**Urban Mobility: System upgrade**

**Why**

Shared self-driving fleets drove more than today’s car fleet in all of the scenarios we tested. Overall car kilometres rose 6% in the TaxiBot plus HC public transport scenario and nearly doubled (+89%) in the AutoVot scenario with no public transport.

This increase can be explained by several factors.

In all scenarios, we assume that shared self-driving fleets completely replace current bus travel in the city. In the base case, average bus occupancy factors are low (20%) and it is plausible that these riders could be better served by a shared self-driving fleet providing door-to-door service. The diversion of bus passengers accounts for approximately 30% of the final car kilometres travelled in the TaxiBot scenarios and nearly 50% of the car kilometres travelled in the AutoVot scenarios.

The remaining travel is due to empty re-positioning of cars in all scenarios as well as to detours for passenger pick-ups and drop-offs in the TaxiBot scenarios.

Additional travel could increase the environmental impacts, especially if the fleets use conventional internal combustion engines. Hybrid fleets would lower these impacts and fully electric fleets would eliminate the tank-to-wheel emissions from all car travel. We modelled electric shared self-driving fleets to gauge the impact of re-charging times and reduced travel range. In the TaxiBot plus public transport scenario, the impact on fleet size was minimal (+2%).

The safety impacts of this additional travel were not tested but it seems reasonable to assume that such a system would reduce potential conflicts among all road users, decrease crash numbers and their severity.
Scenario: Peak hours

What we did

TaxiBots
Ride-sharing

Public transport
(high capacity)

What we found

number of vehicles required to provide the same trips as before: 35%
Even at peak hours, the car reduction effect of shared self-driving fleets is important. We found that many fewer cars than today would be travelling at peak hours though service levels are maintained.

In the TaxiBot plus HC public transport scenario, nearly 65% fewer cars were circulating at peak hours whereas even in the least car-reducing scenario – AutoVots without HC public transport – 23% fewer cars travelled. These findings suggest that shared self-driving fleets could have significant impacts on congestion.

### Congestion

<table>
<thead>
<tr>
<th>Scenario – Peak hours only</th>
<th>Fleet size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (% of baseline fleet)</td>
<td>60 000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TaxiBot Ride-sharing</th>
<th>Fleet size</th>
</tr>
</thead>
<tbody>
<tr>
<td>No high capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>25 867 (43.1%)</td>
</tr>
<tr>
<td>High capacity transport (commuter rail, subway, BRT, LRT)</td>
<td>21 105 (35.2%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AutoVot Car-sharing</th>
<th>Fleet size</th>
</tr>
</thead>
<tbody>
<tr>
<td>No high capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>46 011 (76.7%)</td>
</tr>
<tr>
<td>High capacity transport (commuter rail, subway, BRT, LRT)</td>
<td>33 975 (56.6%)</td>
</tr>
</tbody>
</table>
In our modelled city a shared self-driving fleet would remove the need for all on-street parking freeing an area equivalent to **210 football fields** or almost **20%** of the total kerb-to-kerb street space.
In all observed scenarios, the potential for reduction in parking spots is massive for both on-street and off-street parking.

Considering that off-street parking represents 50,000 spots in the baseline case and that the most parking-intensive scenario - AutoVots without HC public transport – would require 25,621 spots, **on-street parking spots could be totally removed from the streets**, whatever scenario is considered.

This would allow the reallocation of 1,530,000 m² to other public use¹ - equivalent to almost 20% of the surface of kerb-to-kerb street area or **210 football fields** that could be dedicated to non-motorised transport modes, recreational or commercial use.

In the most favourable scenario for parking, a maximum number of 8,901 parking spots would be necessary. Taking 10,000 as a proxy of the total number of required parking spaces, 40,000 off-street parking spaces could then be reallocated, i.e. 1,200,000 m² - the equivalent of almost 170 football fields - which could be used in innovative ways e.g. logistics distribution centres.

¹ assuming 10 m² for each on-street parking space and 30 m² for each off-street parking space (including lanes, ramps, etc.)

### Impacts on parking space

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Parking spots</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline (% of baseline fleet)</strong></td>
<td><strong>203,000</strong>*</td>
</tr>
<tr>
<td>No high capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>11,563 7.2%</td>
</tr>
<tr>
<td>High capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>8,901 5.7%</td>
</tr>
<tr>
<td>No high capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>25,621 16.0%</td>
</tr>
<tr>
<td>High capacity public transport (commuter rail, subway, BRT, LRT)</td>
<td>17,110 10.7%</td>
</tr>
</tbody>
</table>

---

* On-street parking: 153,000 spots. Off-street parking: 50,000 spots
The overall increase in the volume of travel compared to today when shared self-driving vehicles are mixed 50/50 with conventional cars.
Mixing with conventional cars

We tested the sensitivity of our findings to the presence of a legacy fleet of conventional cars. We randomly assigned 50% of trips to conventional cars and 50% to shared self-driving cars. The result was an increase in overall car kilometres travelled in all cases.

The impact of legacy fleets on car numbers varied according to the scenarios considered. In the presence of HC public transport, mixed fleets resulted in 18% to 22% fewer cars whereas without public transport, 3% to 7% more cars were required to carry out today’s trips.

Peak hour fleet requirements increased from 3% to 34% from current levels in three out of the four scenarios we considered. Only in the TaxiBot plus HC public transport scenario were fewer cars needed than today (-9%) in the presence of the legacy fleet. This suggests that congestion could be an issue in a transition situation where legacy fleets mix with shared self-driving fleets.

Parking requirements were lower than today in the presence of legacy cars in three out of four of the scenarios we considered – only in the AutoVot scenario without public transport were 4% more parking places required.

These results suggest that shared self-driving fleets may face some transition issues in the presence of legacy fleets. Unless increases in travel are managed at peak hours, it may be difficult to make a public policy case for self-driving fleets based solely on space and congestion benefits in the presence of legacy cars. Nonetheless, even in these scenarios, these fleets could represent a cost-effective alternative to public transport if the impacts of additional travel are mitigated.
Even accounting for reduced travel range and charging periods during which electric TaxiBots and AutoVots would not be available, only 2% more cars would be necessary than in scenarios with conventionally-fuelled vehicles.
The impact of self-driving shared fleets is significant but is sensitive to policy choices and deployment scenarios. Transport policies can influence the type and size of the fleet, the mix between public transport and shared vehicles and, ultimately, the amount of car travel, congestion and emissions in the city. For small and medium-sized cities it is conceivable that a shared fleet of self-driving vehicles could completely obviate the need for traditional public transport.

Actively managing freed capacity and space is still necessary to lock in benefits. Shared vehicle fleets free up a significant amount of space in the city. However prior experience indicates that this space must be pro-actively managed in order to lock-in benefits. Management strategies could include restricting access to this space by allocating it to commercial or recreational uses, delivery bays, bicycle tracks or enlarging sidewalks. For example, freed-up space in off-street parking could be used for logistics distribution centres.

Road safety will likely improve; environmental benefits will depend on vehicle technology. Despite increases in overall levels of car travel, the deployment of large-scale self-driving vehicle fleets will likely reduce crashes and crash severity. At the same time, environmental impacts are still tied to per-kilometre emissions and thus will be dependent on the penetration of more fuel efficient and less polluting technologies.

Public transport, taxi operations and urban transport governance will have to adapt. The deployment of self-driving and shared fleets in an urban context will directly compete with the way in which taxi and public transport services are currently organised. These fleets might effectively become a new form of low capacity / high quality public transport. Labour issues will be significant but there is no reason why public transport operators or taxi companies could not take an active role in delivering these services. Governance of transport services, including concession rules and arrangements, will have to adapt.
New car models and business models will be required
The drastic reduction in the number of cars would significantly impact car manufacturer business models. New service-based models will develop under these conditions but it is unclear who will manage them and how they will be monetised. The role of authorities, both on the regulatory and fiscal side, will be important in guiding developments or potentially maintaining impediments.

Under all of our scenarios, vehicles are used much more intensely than before – rising from approximately 50 minutes to 12 hours per day and daily travel will increase from approximately 30 kilometres to nearly 200 kilometres. This increase in use will require different car models than are currently on the market today, but also induce a shorter lifecycle and with it a quicker penetration of new, cleaner technologies. Shared use will also require different and much more robust interior fittings though weight savings could potentially accompany a reduction of crash risk. Innovative maintenance programmes could be part of the monetisation package developed for these services.

Mixing shared self-driving fleets with traditional cars will not deliver the same benefits as full fleet deployment, but remains attractive.
Overall vehicle travel will be higher in all fleet-mixing scenarios and vehicle numbers increase in 3 out of 4 of our peak hour scenarios. It is likely that improved traffic flow could mitigate congestion up to a point. In the most extreme scenarios, however, it may be difficult to make a public policy case for self-driving fleets alone (without HC public transport) based solely on space and congestion benefits. Nonetheless, even in mixing scenarios, these fleets could represent a cost-effective alternative to traditional forms of public transport if the impacts of additional travel are mitigated. "All in“ deployment of shared self-driving fleets may be easier in circumscribed areas such as business parks, campuses, islands, as well as in cities with low motorisation rates.
The CPB is a global network of companies from across all transport modes and closely related areas like energy, finance, IT, who understand the opportunities and challenges to transport and want to work with the ITF to improve policy analysis and advice by adding a corporate perspective to the process. The CPB provides a unique avenue for participating in the debate on the challenges and trends facing global transport, and bringing issues important to businesses to the attention of policy makers, key transport stakeholders in ministries, the business community, and international organisations.

The work started in early 2014 and there are currently four projects underway:

• Autonomous Driving: Regulatory Issues
• Urban Mobility: System Upgrade
• Mobility Data: Changes and Opportunities
• Drivers of Logistics Performance: Case Study

This is a background document, with the final report due January 2015.

Contact:
Philippe Crist
T +33 (0)1 45 24 94 47
E philippe.crist@oecd.org
www.internationaltransportforum.org