Framework for Platform Innovation in Urban Mobility Service

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***Abstract*—The increasing concentration of population in urban areas challenges their mobility services. However, the mobility solutions currently in place lack the capacity and scope to match the growing demand for service. In contrast, computer simulations offer a vision of urban mobility in which fleets of vehicles are automated, electric, shared, and connected with supporting infrastructure systems like traffic management, re-charging, and mass transit. Achieving the promise of the simulation models will require an open-architecture innovation platform that can: (a) adopt the innovations in vehicle automation, electric power trains, and connectivity technologies; and (b) provide incentives for continuous innovation to meet the mobility demand of rising populations around the globe. In the paper the authors propose a generic innovation platform that could be deployed in each metro area in consonance with its distinct characteristics.**

***Index Terms*—urban mobility service, mobility sharing models, system-level innovation, platform innovation, ecosystem framework**

I. Introduction – Increasing Urban Mobility Chanllenges

The rising urban population causes the increasing urban mobility demands. Ref. [1] As of 2015, there are 37 megacities in existence, and 50% of the world's population lives in cities today, a figure set to increase 70% by 2020. The figure displays the increasing urban mobility demands. By the year 2050, people living in urban areas are projected to travel 67.1 trillion passenger-kilometers. These growth trends are summarized in Fig. 1.

Due to this aggregation of population, people who live in urban areas have experienced:

- Time and financial loss from traffic congestion
- Urban air pollution
- Urban island heat effect

A. Traffic Congestion

Ref. [2] In 2011, congestion caused urban American to travel 6.9 billion excess hours and to purchase an extra 3.1 billion gallon of fuel for congestion costs of $160 billion. The congestion costs in year 2020 are estimated about $192 billion.

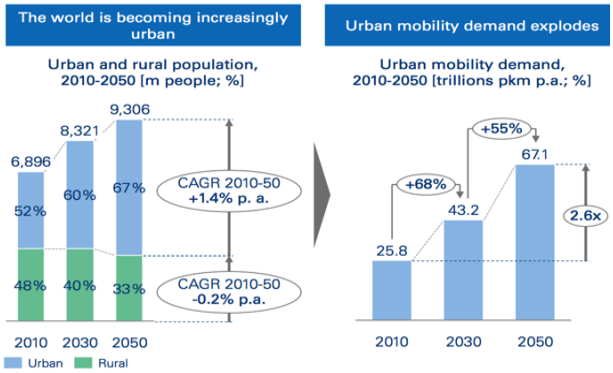

Figure 1. Increasing urban population and mobility demand

B. Urban Air Pollution

Ref. [3] Urban air pollution is linked up to 1 million premature deaths and 1 million pre-native deaths each year. Urban air pollution is estimated to cost approximately 2% of GDP in developed countries and 5% in developing countries. Over 90% of air pollution in cities is attributed to vehicle emissions.

C. Urban Heat Island Effect

Ref. [4] The annual mean air temperature of a city with 1 million people or more can be 1.8 – 5.4 °F warmer than its surroundings. In the evening, the difference can be as high as 12 ° F. Metro areas so affected see increased energy demand at summer peak, higher air conditioning costs, air pollution and greenhouse gas emissions, and heat-related illness and mortality.

This paper introduces the background knowledge of the urban mobility issues in Chapter I. Then the authors propose a vision of the optimized urban mobility system in Chapter II, as well as the overview of the automotive industry evolutions from artificial intelligence perspective. To achieve the visionary stage of urban mobility service, authors identified two essential factors, continuous innovation and a framework for system-level innovation. The authors illustrate the related disruptive technologies and the impact of each in Chapter III. To deliver the solution at system-level, a framework for platform innovation is proposed by the authors in Chapter IV. The framework serves the integration purpose to enhance the efficiency of urban mobility service from a system-level,

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as well as encourage new forms of value creation, and value capture activities in the automotive industry.

II. A Vision for Urban Mobility Service

To understand the vision for urban mobility service, the authors reviewed the history of automation in the automotive industry. Automotive production on a commercial scale started in France in 1890s. Over a century, automakers have been working on optimizing the components of vehicle or vehicle itself. However, the optimized individual vehicle cannot address the urban mobility issues anymore. The disruptive technologies pull and the increasing urban mobility demands push urge the automotive industry to react rapidly in urban mobility service sector. The system-level solution is needed to enhance the efficiency of the transportation system. Fig. 2. illustrates the four significant technical evolution stages in the automotive industry, and points out the developments on artificial intelligence related technologies which lead the pathway to the future visionary urban mobility service.

A. 1890s through 1990s

The vehicle was offered as a complex assembled system, and human drivers were required to develop the skills adequate to make best use of that individual system.

B. 2000 to Present

The vehicle evolved to become a smart and complex system, where human operate the vehicle using driver-assist systems, such as adaptive cruise control to reduce the risks from inattention or automatic parking to supplement underdeveloped or infrequently used skills.

C. Emerging Vehicle Automation

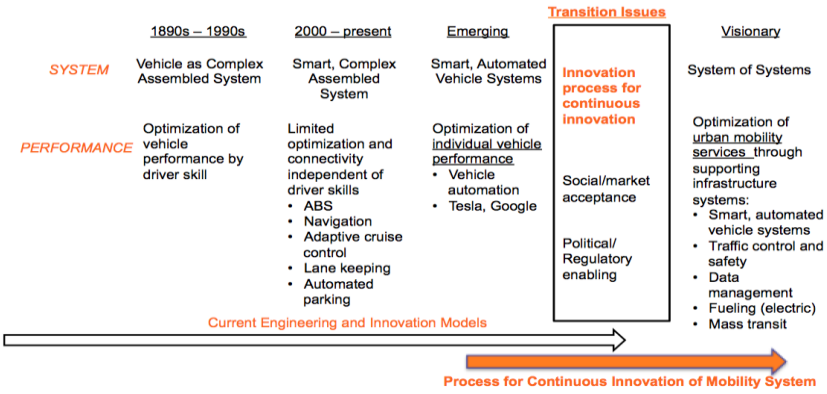

Figure 2. System of systems in urban mobility service

The urban mobility market has now entered the stage of emerging full automation. Tesla, Google, Delphi and others have now demonstrated automated driving technology for individual vehicle.

D. Mobility System Automation: A Visionary Urban Service

The urban mobility service envisioned in the simulation models is able to optimize the overall transportation system's service performance by integrating disruptive technologies such as automated driving, connected vehicle technology and alternative fuel technology under supporting infrastructures. Chief among these infrastructures are traffic management and control, re-charging, mass transit, and data management. In effect it becomes a system of systems.

Throughout the three proceeding stages, the innovations were focused on the product, the automobile, or to state it more inclusively, the light duty vehicle. The competition among automakers, formally known as "original equipment manufacturers", was to understand how the vehicle market could be segmented and to design and manufacture the vehicle fleet best suited for each segment. It has been an essentially product-based competition from the beginning of the industry.

However, the possibility of a fully optimized urban mobility system carries implications for the basis of competition: A disruptive transition from product-based competition to service-based marketplace.

For emerging technology to enable the visionary mobility system, several stages, follow things need to be addressed:

- Continuous technical innovation to enable the visionary urban mobility service
- Engage entrepreneurs to exploit value across industry
- Build system-level innovation process framework to integrate technologies, and business models into a coherent customer-facing solution

During the transition to the visionary mobility service stage, customer acceptance, and the acquiescence of jurisdictions also influence the rate and direction of change. The topics, however, are beyond the scope of this paper.

III. Continuous Innovation – Technical Essentials

The consequences of increasing mobility demands in the urban metro area have encouraged the developments of disruptive technologies. The authors will introduce

electric vehicle technology, and automated driving technology in this chapter, as well as the impacts of different mobility sharing models.

A. Electric Vehicle

Ref. [5] Electric vehicles (EV) are propelled by one or more electric motors powered by rechargeable battery packs. EV itself emits no tailpipe emissions. Ref. [6] Below is the social impacts from shifting to electric vehicles:

- Increase urban air quality due to alternative fuel
- Lower carbon emissions due to energy efficiency
- Decreased urban noise
- Decreased urban heat effect

Compared with conventional gasoline vehicles, electric vehicles convert higher percent of the energy into motion. Therefore, EVs release less heat into the area. A study in 2012 demonstrated that replacement of conventional vehicles by electric vehicles could reduce heat emissions in urban area. Ref. [7] The switch over in Beijing would lower heat island intensity (HII) by 1.7 degrees Fahrenheit and thereby reduce the amount of electricity that would be consumed by air conditionings in buildings by 14.44 million kilowatt hours, and reduce daily CO2 emissions by 10,686tons.

B. Automated Driving Technology

Ref. [8] Automated vehicles are defined by NHTSA (National Highway Traffic Safety Administration) as those in which operations occur without human drivers' directly inputs. NHTSA also classified automation into 5 levels, from level-0 (no automation) to level-4 (fully self-driving vehicle).

Ref. [9] The impacts of fully automated vehicles in urban area are widely understood to include:

- Increased safety
- Increase convenience and productivity
- Increase traffic efficiency
- Enable technology for widespread car sharing

Currently commercially offered partly automated vehicles are at level-2 automation, such as the vehicles with adaptive cruise control function. The Google autonomous vehicle is considered level-3 automation since it does not conduct trips without the possibility that human drivers can take control if needed.

The cost of automated vehicle could be a potential concern to both consumers and OEMs which may delay the technical development process. Ref. [10] The figure from Boston Consulting Group illustrates the additional cost of an automated driving vehicle over the conventional vehicle. The GPS and Lidar are the two most expensive technologies. To bring entire suite of AV features to market, OEMs and suppliers will have to make substantial R&D investments over the next decade to accelerate development and reduce the cost of these components.

Ref. [11] IHS Automotive forecasts that the price for the self-driving technology will add between $7,000 and $10,000 to a car's sticker price in 2025, a figure that will drop around $5,000 in 2030 and about $3,000 in 2035, the year when the report believes that most self driving vehicles will be operated completely independent from a human occupant's control.

The R&D collaborations in partnership across industries are the key to drive the future price down for mass adoption.

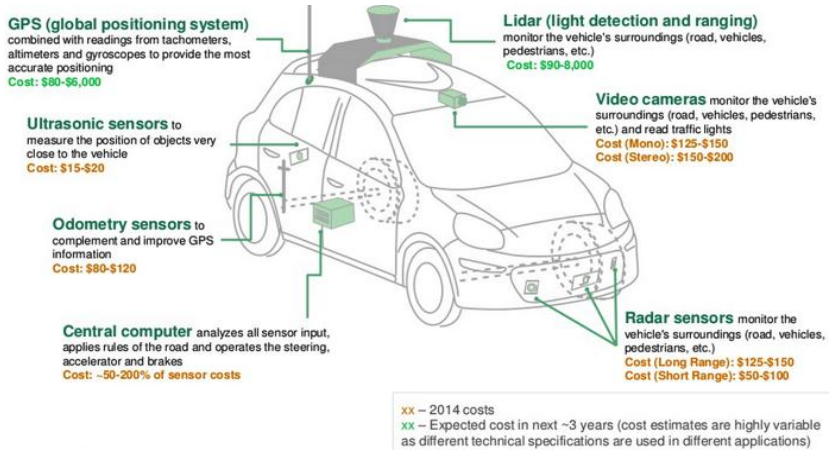

Figure 3. Automated driving hardware and cost

C. Shared Automated Vehicle Models

Deloitte published a study on customer behavior shift in the automotive industry. Traditional customer preference for owning vehicles has shifted in Gen Y (1977 – 1994), who are the demographic cohort following Generation X.

Ref. [12] Gen Y has grown up in a connected world that has changed how they interact with friends, family and world around them. The needs to complete travel tasks that require access to a vehicle are being met by emerging transportation models such as car-and-ride-sharing, improved public transportation. As a result, the basic concept of mobility is being redefined for this group. Vehicle sharing is becoming an increasing component of this redefinition.

Vehicle sharing increases transit efficiency under fixed road infrastructure. Ref. [13], Ref. [14] As applied to the automated vehicle, sharing models could impact in urban area more than the impacts of the automation by itself:

- Increase convenience and productivity
- Increase traffic efficiency and lower congestion
- Enable technology for widespread car sharing

- Increase traffic efficiency – Reduce fleet size at peak hour by 23% - 65%
- Lower parking needs, creating new land use opportunities by reducing on-street parking, and off-street parking

Different automated vehicle sharing models have been proposed under variety sizes of cities. The models all illustrate the significantly reduced vehicle fleets needed to provide equivalent service.

1) Singapore study

The study in Singapore used a Mobility-on-Demand (MoD) system. The MoD system considers arrival rate, average distance between operation vehicles and service demanders, mobility demand distribution, liner earth mover's distance which is a measure od the distance between two probality distributions over a region, and average velocity to calculate the minimum fleet size needed in real traffic to meet mobility demands. The Singapore traffic data is from The Household Interview Travel Survey, Singapore Taxi Data, and Singapore Road Network.

In a real MoD system, passengers would typically wait for the next available vehicle rather than leave the system immediately if no vehicles are available upon booking, the waiting time will not beyond 3 minutes. Ref. [15] As a result, the MoD suggests a shared-vehicle mobility solution can meet the personal mobility needs of the entire population in Singapore with a fleet size is approximately 1/3 of the total number of passenger vehicles currently in operation.

2) Lisbon study

The Lisbon study pointed out especially that the transition from current fleet operational behavior to future sharing autonomy is likely to prove most challenging, and its nature will shape the final configuration of the optimized mobility service.

The study developed a new agent-based model to simulate the behavior of all players of this system: First, the travellers, as potential users of the shared mobility system. Second, the cars, which are dynamically routed on the road network to pick-up and drop-off clients, or to move to, from and between stations. Third, a dispatcher system tasked with efficiently assigning cars to clients while respecting the defined service quality standards. The study is based on a real urban content, the city of Lisbon, Portugal.

Ref. [13] The result shows that:

- Under a 100% shared self-driving fleet scenario, ride sharing model could reduce fleet size to 10.4% - 12.8% of current fleet, when coordinated with the public transportation system
- Under 100% shared self-driving fleet circumstance, car sharing model could reduce fleet size from 16.8% - 22.8% of current when coordinated without the public transportation system
- Under a 50% private car use for motorized trips scenario, both the ride sharing and the car sharing model show insignificant reductions in the needed fleet size and in some cases show increases

The Singapore and Lisbon studies examined the ideal urban mobility system from the perspective of overall reduced fleet size, note that the reduced number of vehicles could relieve certain congestion and air pollution issues. Boston Consulting Group examined urban mobility service from a different aspect, the cost per passenger mile of a shared, automated taxi service.

3) New York City Study

In New York City Study, the "Robo-Taxi" is proposed to offer last-mile solutions by a shared and automated driving Taxi. The shared automated taxis would be owned and operated by mobility providers – taxi service operators, ride sharing services, new entrants from the technology sector, OEMs – and "rented" to consumers by the minute or the mile.

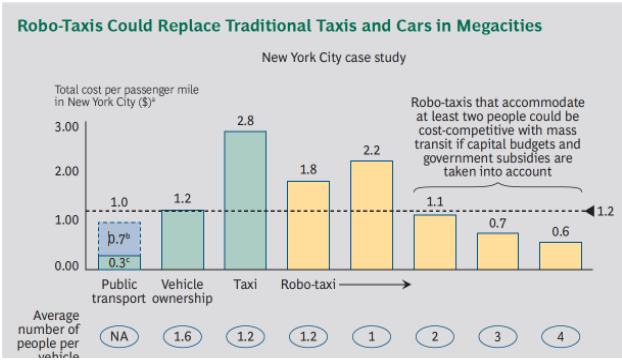

Figure 4. Robo-Taxi service in New York City

Ref. [10] Fig. 4. shows the cost per passenger mile of the Robo-Taxi service. The cost of conveying one passenger one mile by Robo-Taxi would be 35% less than doing so by conventional taxi at the average taxi occupancy rate of 1.2 passengers. From a provider's perspective – and factoring in the full cost of public transit, including government subsidies – Robo-Taxis would become competitive with mass transit at an occupancy rate of 2 passengers.

Overall, all the studies about the shared automated vehicle service model have proved the potentials in reducing fleet size, and providing service at an affordable level. The new form of service offered and the relatively lower operational cost will encourage the ride-sharing trend, regulation progress, and new forms of entrepreneurships in mobility market place.

D. Optimized Network

In the visionary urban mobility service, the technologies could not stand in isolation to achieve the goal. All the technologies had to be linked to the system or infrastructures to optimize the performance. To support this, the data exchange actives among transport operators/providers, transport users, and third party developed applications must form the backbone of the system.

Such data exchange activities also provide insights on customer behaviors and utility usage to maximize the infrastructure capacity. Ref. [16] The integrated technologies under an optimized network with the insights learned from big data form an intelligent transportation

which enables the wide spread car sharing, and offers system-level mobility solutions.

IV. Continuous Innovation and Innovation System – Current Innovation Processes in Use

The authors have illustrated the technical essentials to achieve the visionary stage. However, the transition between current technical stage and future ideal urban mobility service is not going to be addressed without an efficient innovation framework.

Innovations are defined as new ideas, improvements or solutions that are implemented and transferred into useful out comes. Not all creative ideas become innovations but only if they are implemented and adopted in a beneficial way. The innovation process to enhance technical innovations and implement solutions in reality is the key to transferring the idea into products. Singular innovations alone cannot unlock the full power of advanced technologies for road mobility. In addition, large-scale, timely innovation will require platforms to compete effectively with the incumbent business models and technologies. Ref. [17] The most effective innovation systems will find ways to include entrepreneurs in a predictable, systematic manner.

Figure 5. Apple platform innovation ecosystem

A. Traditional Innovation Processes

Traditional innovation processes are able to optimize single systems" performance and reduce the cost of goods sold at product level. They lack of the scope to integrate the optimized urban mobility service.

Common innovation processes used currently include:

- R&D investment partnerships,
- Corporate venture capital investments, and
- Research and commercialization alliances.

B. Platform Innovation Ecosystem

Ref. [18] An innovation ecosystem, defined as the collaborative arrangements through which firms combine their individual offerings into a coherent customer-facing solution, is needed to address the scope of the visionary urban mobility service by definition. Ref. [19] An innovation ecosystem includes economic agents and economic relations as well as the non-economic parts such as technology, institutions, sociological interactions and the culture.

An innovation ecosystem can be a hybrid of different components, networks, or systems. Ref. [20] The collaborative arrangements might be based on local concentrations of industry, such as Porter's clusters, but the ecosystem model has expanded the idea of local clustering to encompass a global, networked economy and various interdependent actors. Innovation ecosystems expand the innovation process from internal R&D activities to numerous co-creators, and co-innovators.

Ref. [21] Fig. 5 shows that Apple offers a variety of products from software to hardware. About 80% of Apple's revenue comes from hardware sales; however, the 20% comes from selling software helps drive future hardware sales as customers lock-into this platform. Apple engages the entrepreneurs during the software create stage to provide diverse interesting content to attract users.

C. Innovation Framework in Urban Mobility Service

To apply platform innovation ecosystem thinking to optimize urban mobility service, the authors have created the framework, which is shown in Fig. 6. This is the framework implied in the models cited above, one that if implemented could deliver the service improvements promised in silica into the real world.

The exact configuration of each innovation platform will vary with the culture, economy, and political organization of each metropolitan area. Here we propose a generic innovation framework that could be deployed in each metro area in consonance with its distinct characteristics. This is shown in Fig. 6.

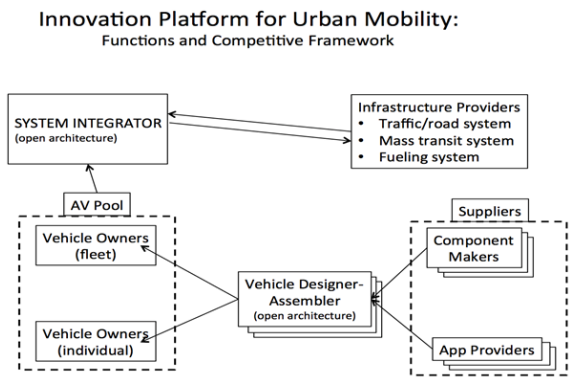

Figure 6. Innovation platform for urban mobility

The functional components common to all applications of this framework would include: (a) A system integrator, either a public agency or regulated monopoly, charged with stewardship of the entire innovation ecosystem; (b) a pool of automated vehicles owned by fleets or by private individuals, dispatched through a common platform analogous to the Uber platform, and competing among themselves to provide customer service; (c) the designers and assemblers of the automated vehicles, who would compete for sales to the fleets and private owners; and (d) the suppliers to these designer/assemblers.

By one means or another, and accounting for all cultural, economic and political circumstances, all these functions will have to be in place to gain the greatest benefit from any innovation platform serving urban mobility.

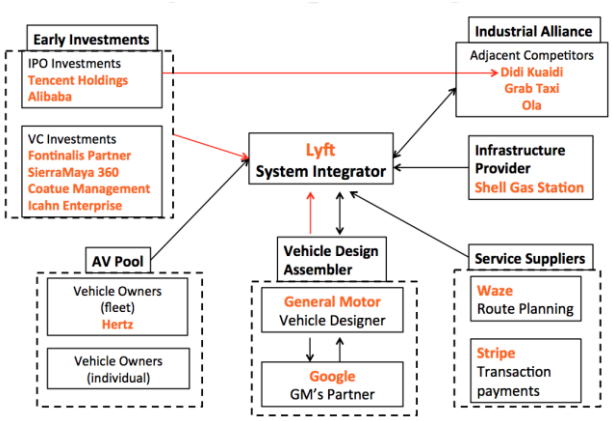

Figure 7. Lyft's innovation ecosystem in urban mobility service

The authors demonstrated a platform innovation example with the firm Lyft (see Fig. 7.) Lyft is a ride-sharing service provider that has deployed the service in 32 states in the U.S. In this innovation ecosystem, Lyft serves as a system integrator, provides the sharing application and harnesses the power of industrial partners. Lyft leverages different forms of resources from investors, individual and cooperation fleet owners, service suppliers, vehicle design assemblers and industrial alliance to provide urban ride-sharing service. In the figure, the red arrows represent the investment activities, and the black arrows represent the partnership.

In conclusion, an innovation platform built upon this framework would:

- Encourage continuous innovations and engage entrepreneurs,
- Coordinate these innovations with the critical economic agents and non-economic agents in the process,
- Instruct the collaborations among the participants,
- Integrate individual technologies into a coherent mobility service, and
- Bring the service into reality by addressing the customer acceptance issues and the acquiescence of metropolitan jurisdictions.

V. Conclusion

The increasing urban mobility demands under fixed road infrastructures challenges the mobility service in metropolitan areas with high and growing population density. Current urban mobility solutions cannot address these challenges sufficiently. In addition to meeting the increasing urban mobility demands, the improved urban mobility service should also relieve the metro area consequences, such as traffic congestion, air pollution, and the urban heat effect.

Pervious researchers have generated simulation models of urban mobility services. The results show the promise of the complete system, but bringing the innovation ecosystem implied by the models challenge can be met will vary depending upon the unique economic, cultural, and political circumstances that obtain in each of the adopting mega-cities.

In all cases, a framework similar to that proposed here will be required if the benefits of advanced technology and the innovative zeal of entrepreneurs are to be applied to the urban mobility challenge.

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