“Dynamic Shared Autonomous Electric Vehicle Fleet Operations”

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Outline

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- Emerging Mobility Technologies
- Modelling User-Driver Meeting Function
- Proposed Model:
  - (1) Maximizing Social Welfare
  - (2) Proportional Fairness
- References

Research Motivation

- Urban transport systems face many obstacles that are set by some of megatrends as:
  (1) Hyper-urbanization
  (2) Societal and demographic changes
  (3) Climate change

- Emerging mobility technologies researches show some promising results in utilizing our limited mobility-resources to achieve our sustainable development goals.

Emerging Mobility Technologies

1- Shared Mobility:

[i.e. car-sharing (Car2Go), ride-sourcing (Uber & Lyft), and ride-sharing (UberPool & Lyft Line)]

- Reducing car ownership [**Chen, Kockelman, and Hanna (2016)** and **Yu *et al.* (2017)**]
- Reducing GHG emissions [**Martin and Shaheen (2016)** and **Yin *et al.* (2018)**]
- Reducing vehicle-miles-travelled [**Clewlow and Mishra (2017)** and **Martinez and Viegas (2017)**]
- Reducing parking demand [**Dia and Javanshour (2017)** and **Zhang and Guhathakurta (2017)**]
- Reducing alcohol-related crashes [**Peck (2017)** and **Morrison *et al.* (2018)**]

Emerging Mobility Technologies

1- Shared Mobility:

[i.e. car-sharing (Car2Go), ride-sourcing (Uber & Lyft), and ride-sharing (UberPool & Lyft Line)]

- Inconclusive impact on public transit [**Clewlow and Mishra (2017)** and **Erik and Nicole (2019)**]
- Attracting taxi users [**Martin and Shaheen (2016)** and **Wang, Zheng, and Lim (2018)**]

Emerging Mobility Technologies

2- Autonomous Vehicles:

- AVs can safely and near-instantaneously receive and execute changes in vehicle planes *(e.g. routes, schedules, and traveler assignments)* coming from the fleet operator *(i.e. a central computing system).*
- From a fleet management perspective, the biggest advantage of AVs is their guaranteed compliance with these real-time plan changes, and more generally the fleet manager's operational policies.
- With complete operational control, the fleet operator can ***maximize the profit of the fleet*** rather than allowing ***drivers to maximize their own profit*** (as in Uber, etc.).

Emerging Mobility Technologies

3- Electric Vehicles:

- Decreasing transport-related GHG emissions
- Increasing high-efficiency vehicle cost-effectiveness

[**Greenblatt and Saxena (2015)**, **Wu and Zhang (2017)**, **Moro and Lonza (2018)**, and **Teixeira and Sodré (2018)**]

- Introducing an integrated infrastructure approach in our proposed model

Modelling User-Driver Meeting Function

Modelling User-Driver Meeting Function

Users

Fleet Operator

Problem Characteristics:

- Users request rides dynamically via a mobile application.
- Users want to be picked up immediately.
- The fleet operator receives users’ requests and assigns AVs to them.
- The fleet operator has complete control over each AV.
- Users will always be served (i.e. the fleet operator cannot reject requests).
- The fleet operator seeks to attain a specific objective function.
- The fleet size is fixed.
- AVs in the fleet are functionally homogeneous.
- Homogeneous population of users

Modelling User-Driver Meeting Function

Users

Fleet Operator

- Objectives:

- Maximizing the number of users
- Minimizing the users’ waiting times
- Minimizing the total travelled distance between users and AVs
- …. etc.

- Performance Indicators:

- Average user waiting time
- Raito of empty fleet miles to total fleet miles
- VMT savings
- …. etc.

Modelling User-Driver Meeting Function

Shared
Vehicles

Shared Vehicles
W/ Shared Rides

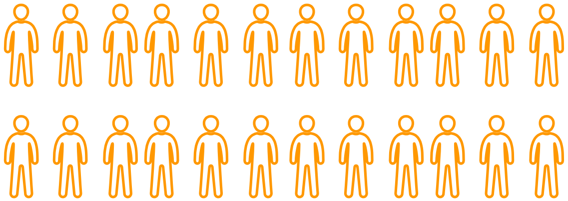
Shared Vehicles
W/ Predictive Demand
Model

(e.g. on-demand taxis)

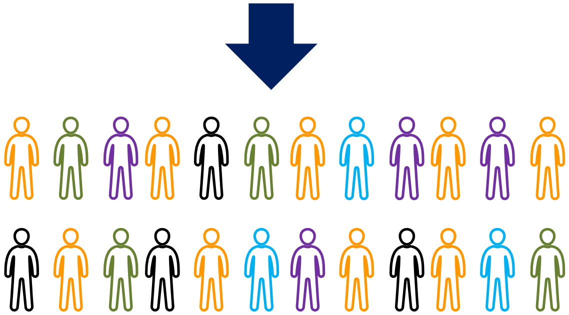
(e.g. UberPool)

Our Proposed Model

Our Proposed User-Driver Meeting Function

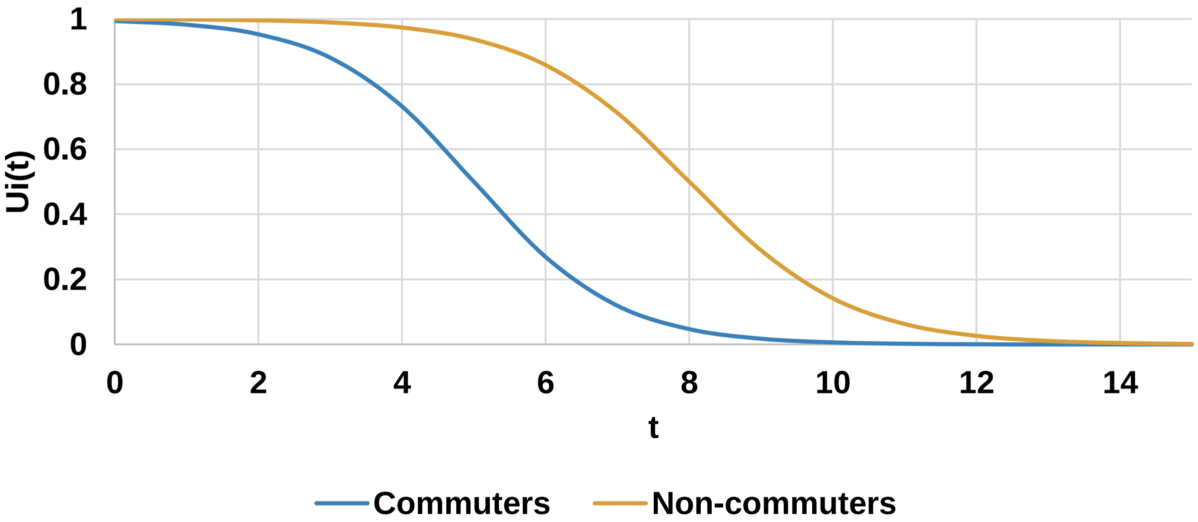


Homogeneous Users Population



Heterogeneous Users Population

For example, ***commuters*** and ***non-commuters*** case:



Our Proposed User-Driver Meeting Function

1- Maximizing Social Welfare :

$$\max_{x_{ij}} \sum_{i \in R} \sum_{j \in V} x_{ij}\, U_i(.) \qquad (1)$$

- $\boldsymbol{R}$ denotes the set of users.
- $\boldsymbol{V}$ denotes the set of AVs.
- $\boldsymbol{i}$ denotes a user in which $\boldsymbol{i} \in \boldsymbol{R}$.
- $\boldsymbol{j}$ denotes an AV in which $\boldsymbol{j} \in \boldsymbol{V}$.
- $\boldsymbol{x_{ij}} \begin{cases} 1 & if\ AV\ (\boldsymbol{j})\ is\ assgined\ to\ user\ (\boldsymbol{i}) \\ 0 & otherwise \end{cases}$
- $\boldsymbol{U_i}(.)$ denotes the utility function of user (*i*)

Our Proposed User-Driver Meeting Function

2- Proportional Fairness :

- The concept of proportional fairness was introduced by **Kelly (1997)** in the area of computer networks.
- Proportional fairness attempts to balance between *efficiency* and *fairness*.
- Proportional fairness was introduced in the context of emergency evacuation by **Aalami and Kattan (2018)**:

$$\sum_{i \in R} \frac{U_i(x_i) - U_i(x_i^*)}{U_i(x_i^*)} \leq 0 \qquad \textbf{(2)}$$

Our Proposed User-Driver Meeting Function

Shared Vehicles

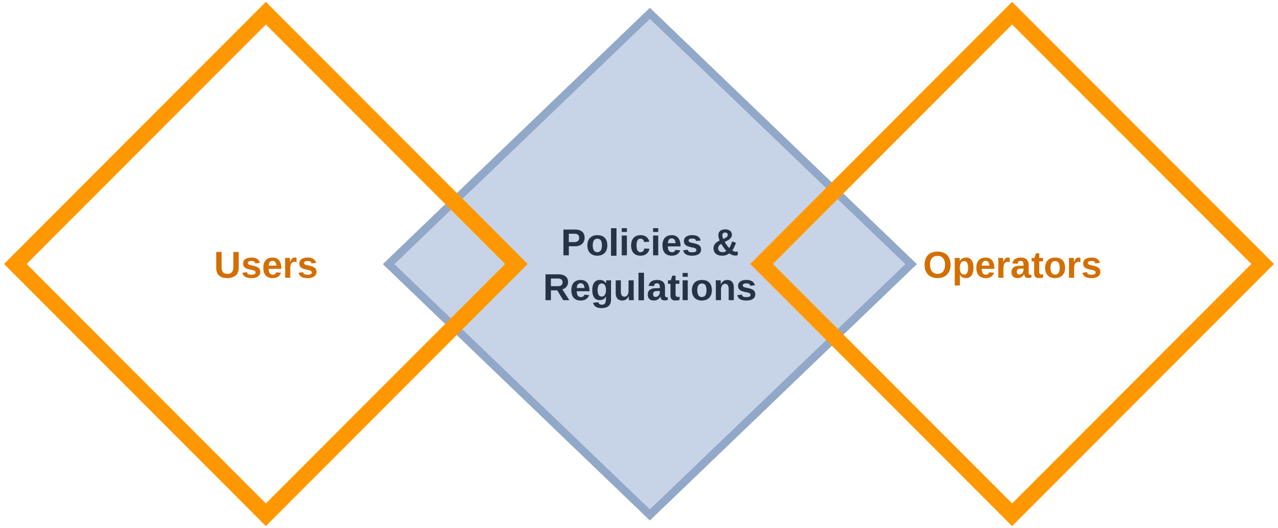
(e.g. taxis)

Shared Vehicles W/ Shared Rides

(e.g. UberPool)

Shared Vehicles W/ Predictive Demand Model

In Nutshell



- Considering policies & regulations concerning ***social welfare***, ***proportional fairness*** and ***transport-related GHG emission reduction goals***.

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Thank You!

Any questions?

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