Photo by Matheus Bertelli from Pexel

An optimization model of automated taxis in trip assignment under elastic demand for the last mile problem

First Research Seminar of the hEAT Lab

Dr. ir. Xiao Liang

Postdoc Researcher

x.liang@tudelft.nl

hEAT Lab
Electric and Automated Transport Research

TU Delft

06.12.2019

What is the system we want to study?

Automated taxi (AT)

Automated vehicle

Taxi

We consider automated vehicles using as taxis and aim at identifying their role in urban mobility systems.

TU Delft

What is the system we want to study?

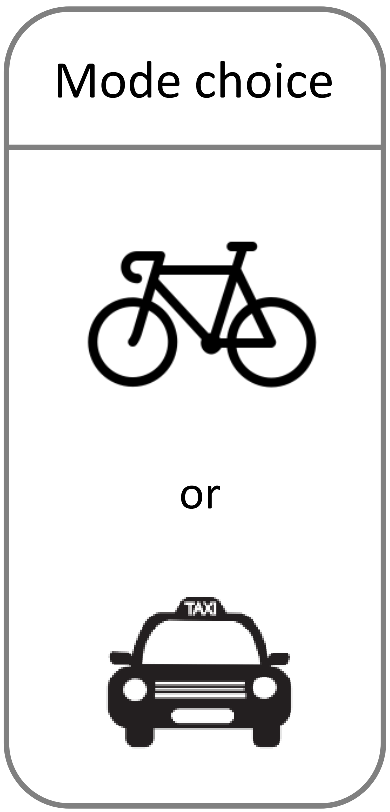
First / last mile problem

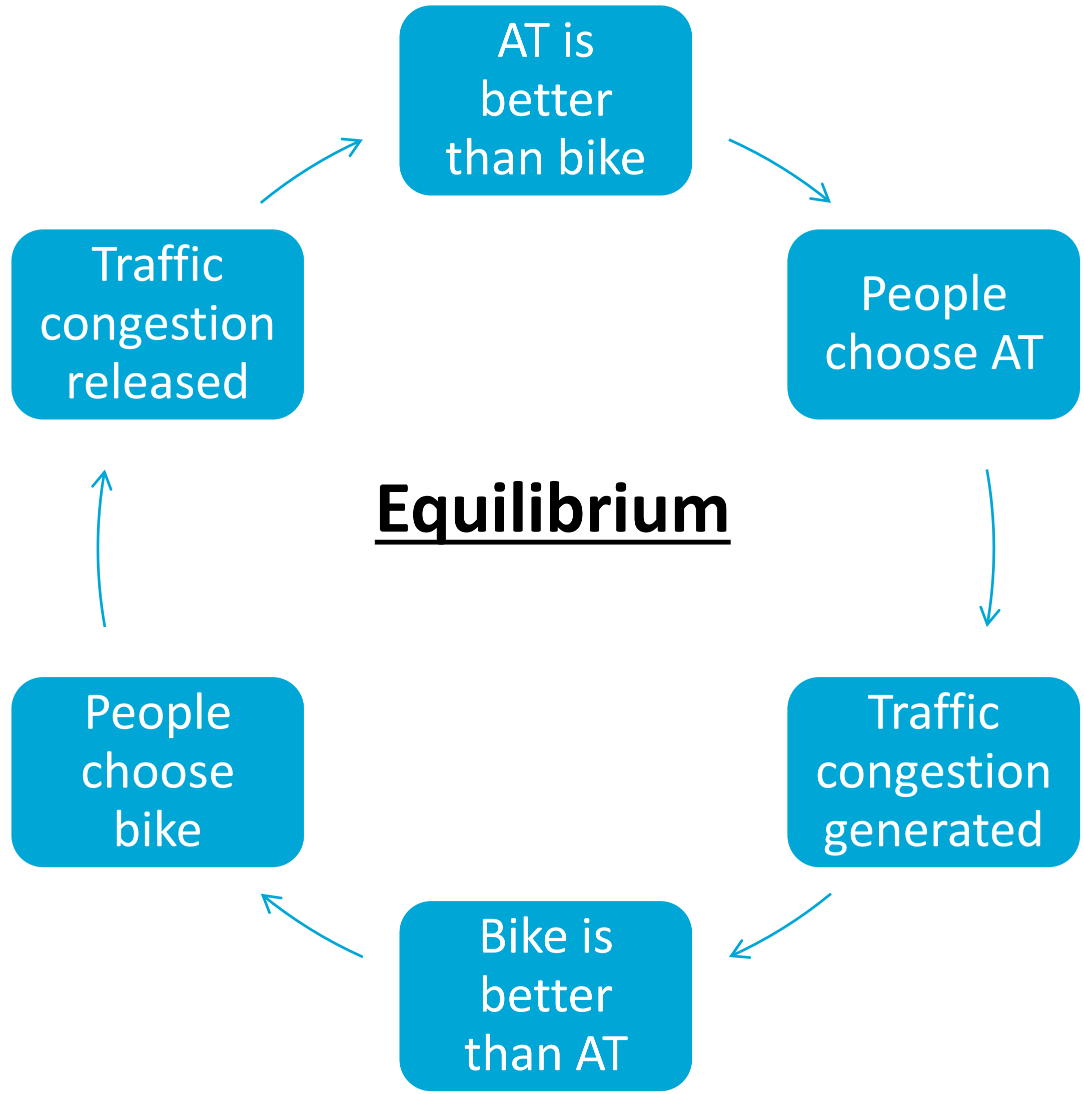
We study an AT system that provides accessibility to and from train stations. We aim to get a clear insight into the system optimization from the system planner's point of view.

TU Delft

What is the system we want to study?

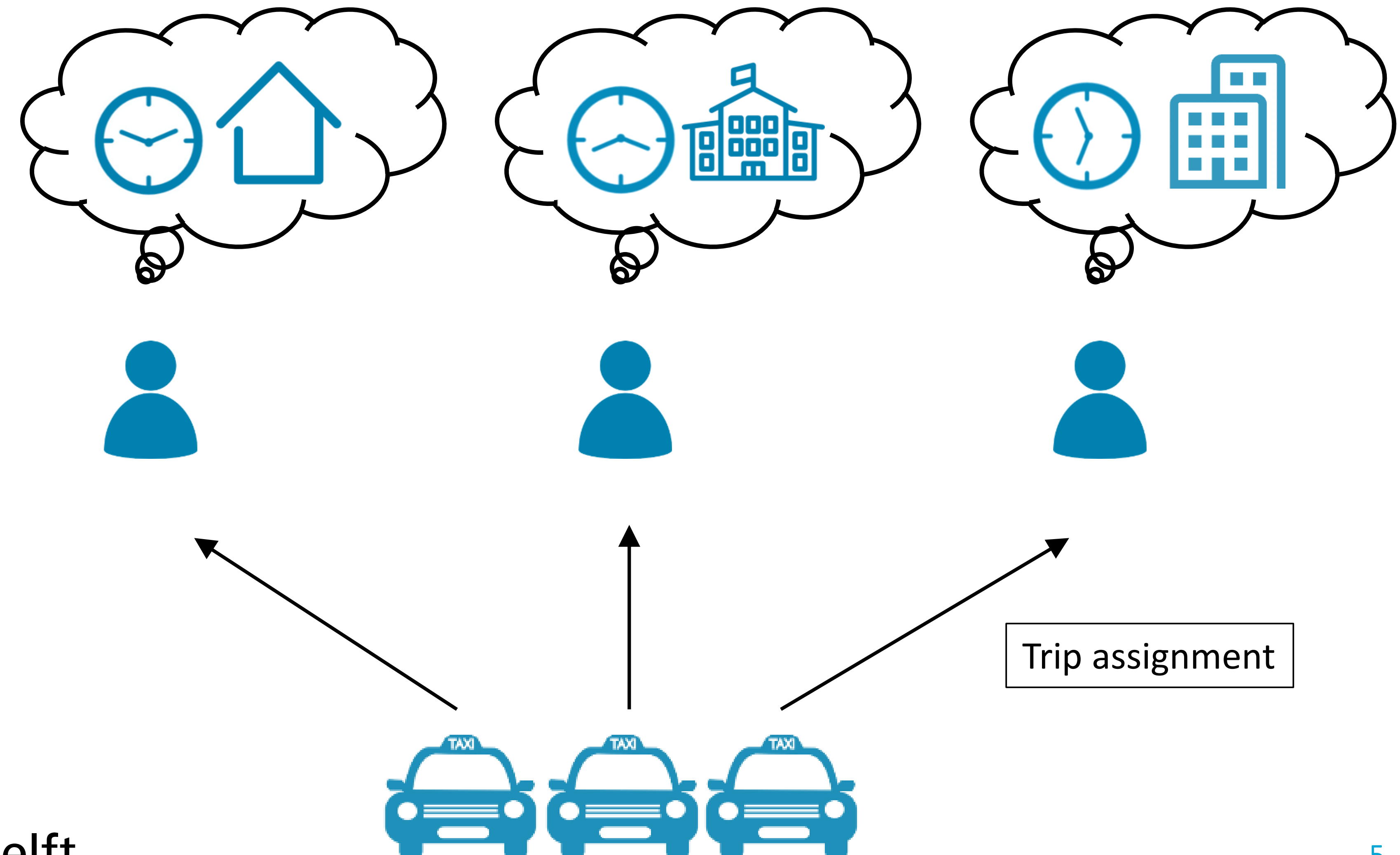
Mode choice





What is the system we want to study?

What we want to know from this model?



Trip assignment

What is the system we want to study?

Key words

- Shared mobility
- Choice modelling
- First/last mile problem

Assumption

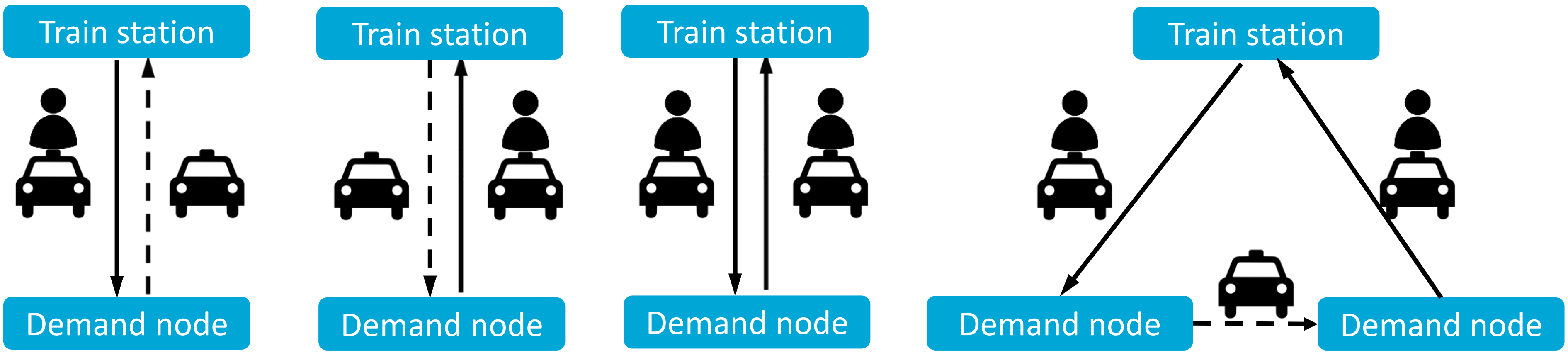
- Two travel modes are considered: by AT and by bike.
- Total demand for AT and bike is fixed.
- Travel time of AT is dynamic based on the traffic flow.

Output

- Optimize the fleet size
- Design the ATs’ routes

Model formulation

System setting



Objective function: minimize the total cost by AT and by bike

AT depreciation cost

Travel time cost

AT fuel cost

TU Delft

Model formulation

Constraints: choice modelling

Utility

Travel time

$$U_{ijt}^{AT} = -r^{AT} \cdot d_{ij} - T_{ijt}^{AT} \cdot a, \qquad \forall \in (i,j)\epsilon\boldsymbol{K}, t \in \boldsymbol{M}$$

$$U_{ij}^{B} = -t_{ij}^{B} \cdot a, \qquad \forall \in (i,j)\epsilon\boldsymbol{K}$$

Probobility

$$P_{ijt}^{AT} = \frac{\exp(U_{ijt}^{AT})}{\exp(U_{ijt}^{AT}) + \exp(U_{ij}^{B})}, \qquad \forall \in (i,j)\epsilon\boldsymbol{K}, t \in \boldsymbol{M}$$

Non-linear

Constraints: dynamic travel time

Travel time

Flow

$$T_{ijt_1} = t_{ij}^{min} \cdot \left(1 + 0.15 \cdot \left(\frac{S_{ijt_1t_2} + v_{ijt_1t_2}}{cap_{ij}}\right)^4\right), \qquad \forall \in (i,j)\epsilon\boldsymbol{K}, t \in \boldsymbol{M}$$

TU Delft

Solving algorithm

Customized gradient algorithm

Initialize each $P = 0.5, \forall \in (i,j) \epsilon K, t \in M$

- *Calculate the value*

  Q:served demand by AT U: utility T: travel time

- *Solve the optimization model*

  $Obj.$: objective function value S: traffic flow F: fleet size

Stopping criteria?

Yes → Stop

No

- *Calculate the partial derivative of each P to Obj. (descent direction)*
- *Calculate the step size*
- *Update each P*

$$P = P - step\ size * descent\ direction$$

Case study

Small case example

Zone 1	Zone 2
Train station	Zone 3
Zone 4	Zone 5

- Demand zones: 5
- Time length: 5 hours
- Requests: 132

Results

Initial value variation

Price rate: 0.5 €/min

Initial value of P	Obj. value (€)	Number of iterations	Fleet size	Total ticket cost (€)	Total travel time (hour)	Share of AT
30%	744.0	5	20	120.0	35,3	36%
50%	658.5	7	19	167.5	26,7	51%
70%	695.0	3	23	175.0	24,4	53%

TU Delft

Results

Price rate variation

P initial value: 50%

Price rate (€/min)	Obj. value (€)	Fleet size	Total ticket cost (€)	Total travel time by AT (hour)	Total travel time by bike (hour)	Satisfied requests by AT	Share of AT
0.5	658.5	19	167.5	12.5	14.2	67	51%
0.4	761.0	15	90.0	10.9	32.5	45	34%
0.3	703.5	18	85.5	14.0	22.5	57	43%

Conclusion

1. This customized gradient algorithm is able to **find a good solution** to the original non-linear model.

2. **Initial values of P** is a **critical control parameter** with respect to the final best solution.

3. **AT service price rate** is a key issue that **affects** the utility of AT and the result of mode split.

TU Delft


Photo by Matheus Bertelli from Pexel

Thank you!

First Research Seminar of the hEAT Lab

Dr. ir. Xiao Liang

Postdoc Researcher

x.liang@tudelft.nl

Electric and Automated Transport Research

TU Delft

06.12.2019