JAGIELLONIAN UNIVERSITY IN KRAKÓW

Performance Optimization of the Platforms in Two-sided Mobility Market

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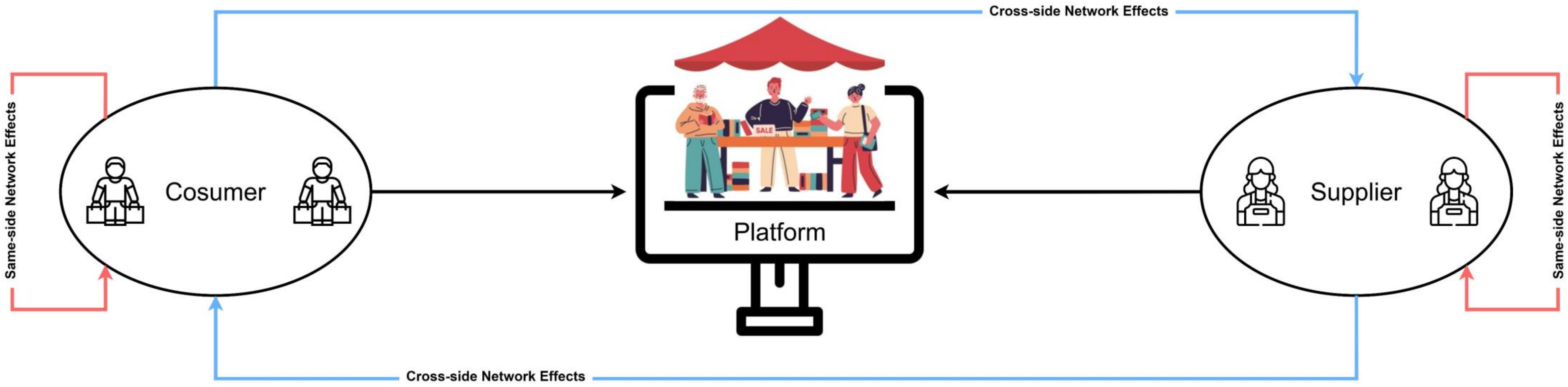
NATIONAL SCIENCE CENTRE POLAND

Horizon Europe

Agenda

- Two-sided Mobility Markets
- MoMaS Framework
- RL Integration

Two-sided business model



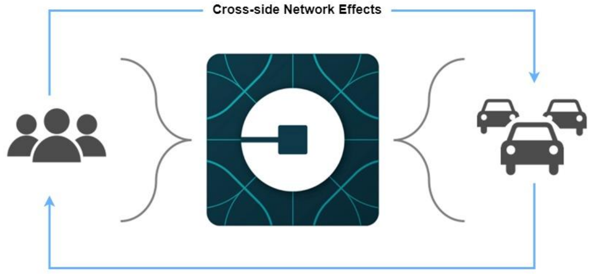
- Cross-side/Same-side NE: the value for one side of a network increases/decreases by adding users to the other/same side

- With positive NE utility and with negative NE disutility is produced

Two-sided mobility Market

- Travellers make trip request
- Drivers supplies travelers' mobility need
- Platforms match demand to supply (private & pooled)

- Policymakers/Regulators
- General public



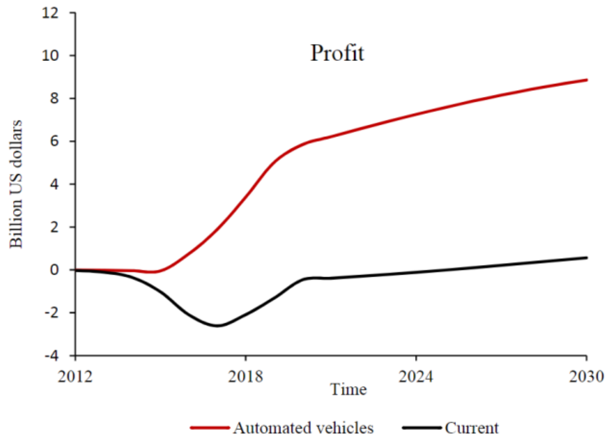
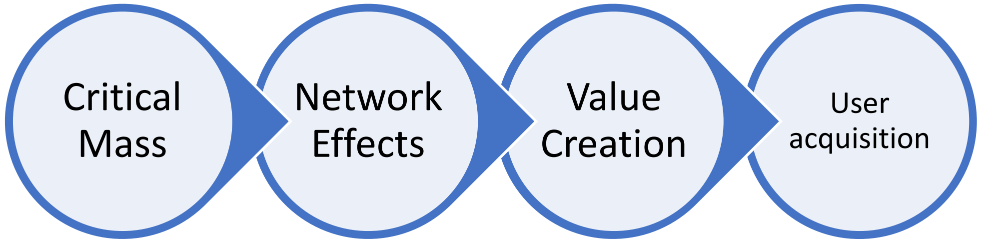


Fig 1. Uber profitability and the impact of AVs (Sun et al., (2022))

Two-sided mobility platforms grow rapidly, yet they are not/barely profitable.

Two-sided mobility Market



Growth Hurdles:

1. Decentralized supply and demand
2. Conflicting interests of parties
3. Regulations

Understanding how platforms grow and what is their optimal growth pattern is of paramount importance not only to the platforms themselves, but also to other stakeholders (policy makers, general public), interested in predicting and controlling their potentially disruptive impact on the economy.

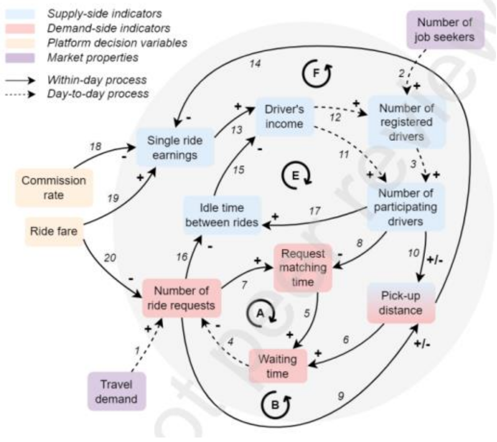


Fig 2. Conceptual representation of the ride-sourcing market (de Ruijter et al.,(2022))

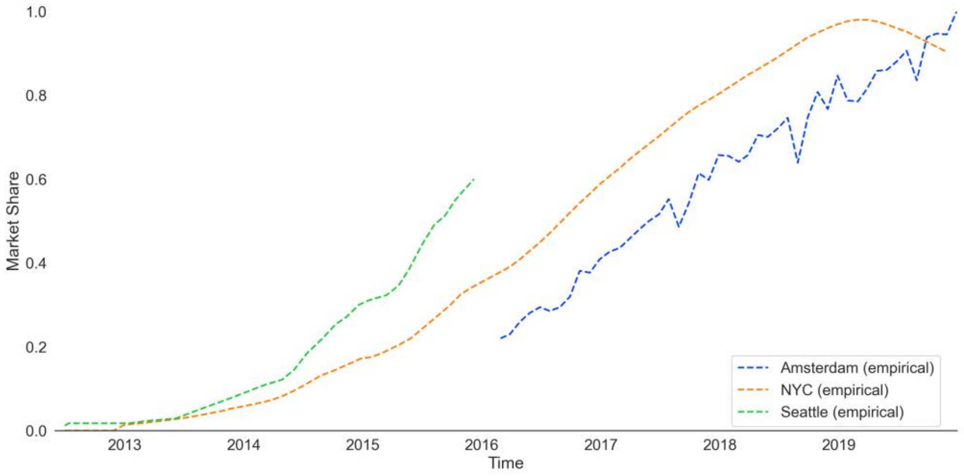


Fig 3. Empirical growth patterns for two-sided mobility platforms.

Empirical vs State-of-art

Majority of studies are:

- Addressing a specific problem neglecting the system interactions
- Equilibrium-based and assuming fixed demand and/or supply
- Relying on deficient learning models

Thus, they are not adequate to understand the complex dynamics underlying the platform growth mechanism.

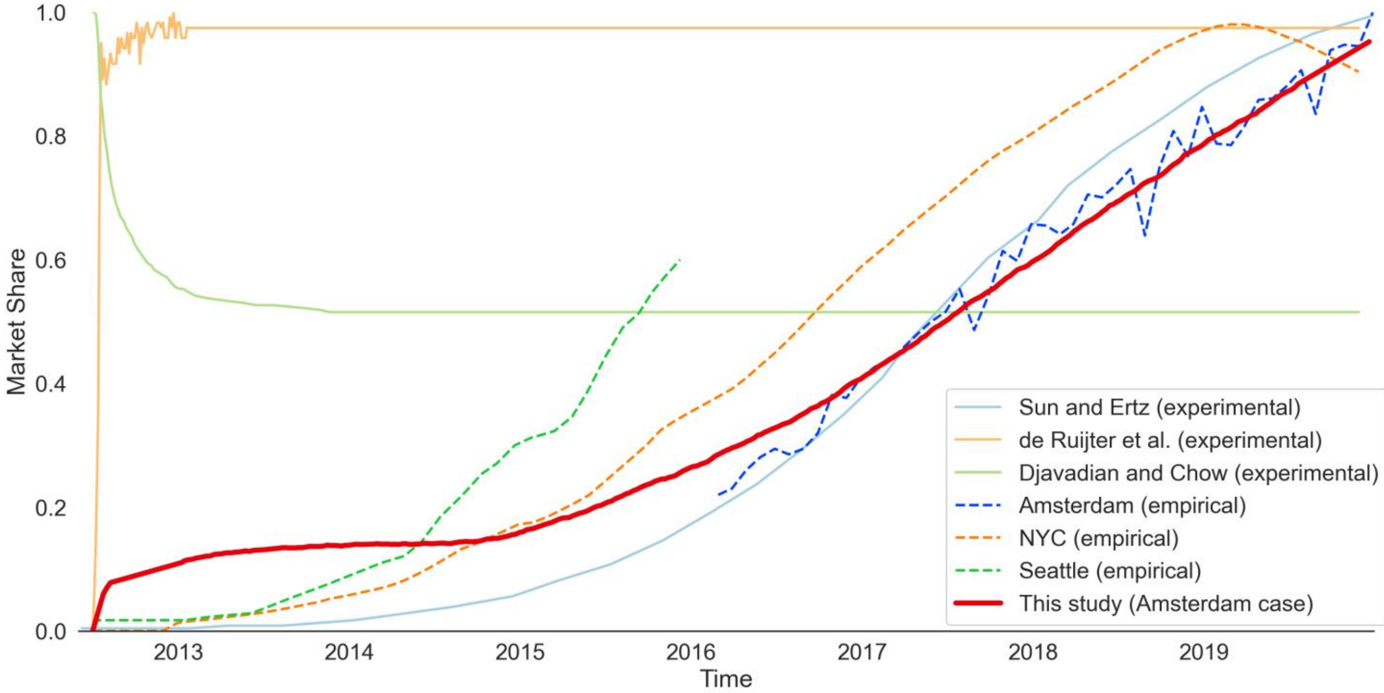


Fig 4. Our model against Empirical and state-of-art

MoMaS (Two-sided Mobility Market Simulation) Framework

MoMaS (Two-sided Mobility Market Simulation) Framework is an adaptive, co-evolutionary framework to capture the day-to-day dynamics of ride-sourcing system and reproduce the platform's growth mechanism.

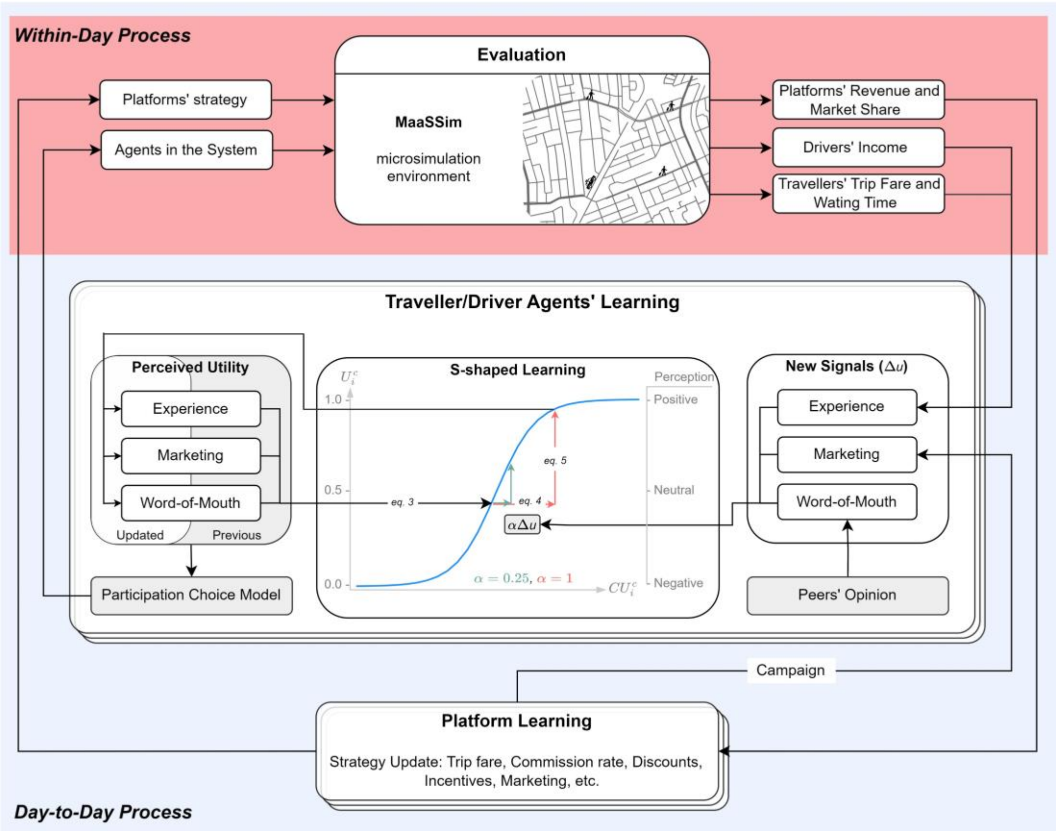
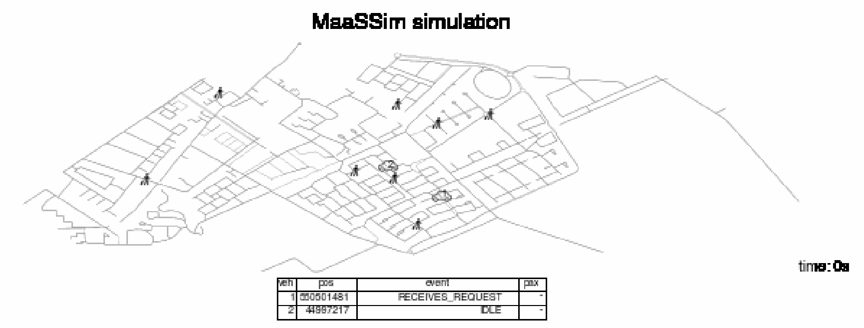


Fig 5. MoMaS at glance.

MaaSSim

Agent-Based Modeling (ABM), as a bottom-up microscopic approach, is a powerful tool to model independent decision makers (agents) with different tastes and preferences, as well as interactions between them.

MaaSSim is an open-source agent-based simulator in *Python* which reproduces the dynamics of the two-sided mobility platforms on the road network graph. (https://github.com/Farnoud-G/MaaSSim)



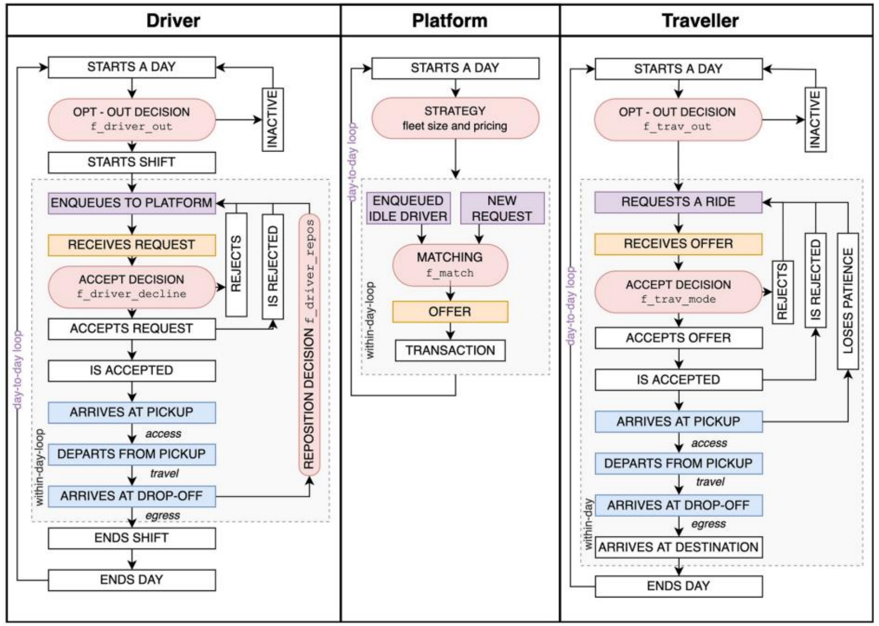


Fig 6. MaaSSim structure (Kucharski and Cats., (2022))

Choice Modelling (Based on Random Utility Theory)

Platform strategy on day t

$$S_t = \{f_t, c_t, d_t, i_t, m_t\}$$

Choice set of (notified) traveler r

$$C_r = \{pt, rs\}$$

Choice set of (notified) driver d

$$C_d = \{rw, rs\}$$

Perceived utility $(U_{i,t})$ mainly depends on experienced utility (U_i^E), but multiple components can be considered such as word of mouth utility (U_i^{WOM}), and marketing utility (U_i^M).

$$U_{i,t} = \beta_i^E . U_{i,t-1}^E + \beta_i^{WOM} . U_{i,t-1}^{WOM} + \beta_i^M . U_{i,t-1}^M + ASC + \varepsilon_i$$

$\beta_i^E, \beta_i^{WOM}, \beta_i^M > 0$ and $\beta_i^E + \beta_i^{WOM} + \beta_i^M = 1$

Probability of choosing alternative m for agent i on day t is calculated with the classic logit model:

$$P_{i,t}^m = N_{i,t} \frac{exp(\frac{U_{i,t}^m}{\theta})}{\sum_{m' \in C_i} exp(\frac{U_{i,t}^{m'}}{\theta})}$$

$N_{i,t}$ *equals* 1 *if the agent is notified, otherwise* 0

Day-to-day Learning

All the previous studies are based on Exponential Markov model proposed by Bogers., et al (2007) for route choice: $U_t^{expected} = (1-\alpha)U_{t-1}^{expected} + \alpha U_{t-1}^{actual}$

- Too sensitive regardless of learning state
- Learning never stabilizes

We proposed S-shaped adjustment mechanism providing a realistic representation of growth pattern.

- Based on psychological principles
- Sensitivity depends on the learning state
- Stabilizes (It is bounded)

$$CU_{i,t-1}^{c} = ln\left(\frac{1}{U_{i,t-1}^{c}} - 1\right)$$

$$CU_{i,t}^{c} = CU_{i,t-1}^{c} + \alpha.\Delta u_{i,t}^{c}$$

$$U_{i,t}^{c} = \frac{1}{1 + exp(CU_{i,t}^{c})}$$

α is learning degree

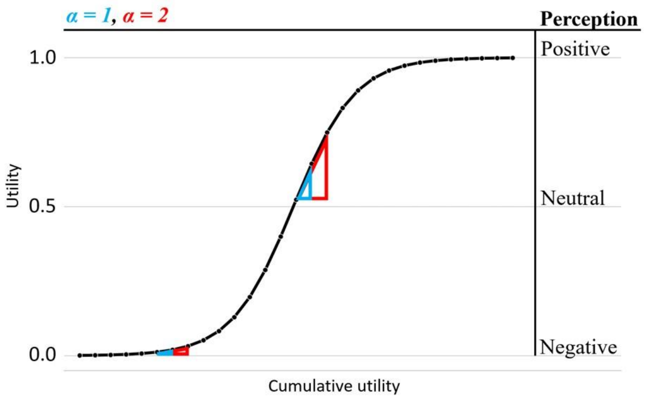


Fig 7. S-shaped adjustment mechanism

Amsterdam Case Study with a Pool of 10000 Travelers and 1000 Drivers

Table 1. The six-stage market entry strategy adopted by the platform.

Day	Stage number	Name	Marketing	Commission	Discount
0 – 25	I	Kick-off stage	No	10%	–
25 – 50	II	Discount stage	No	10%	40%
50 – 100	III	Launch stage	5 [€/agent/day]	10%	40%
100 – 400	IV	Growth stage	No	10%	40%
400 – 600	V	Maturity stage	No	10%	–
600 – 700	VI	Greed stage	No	50%	–

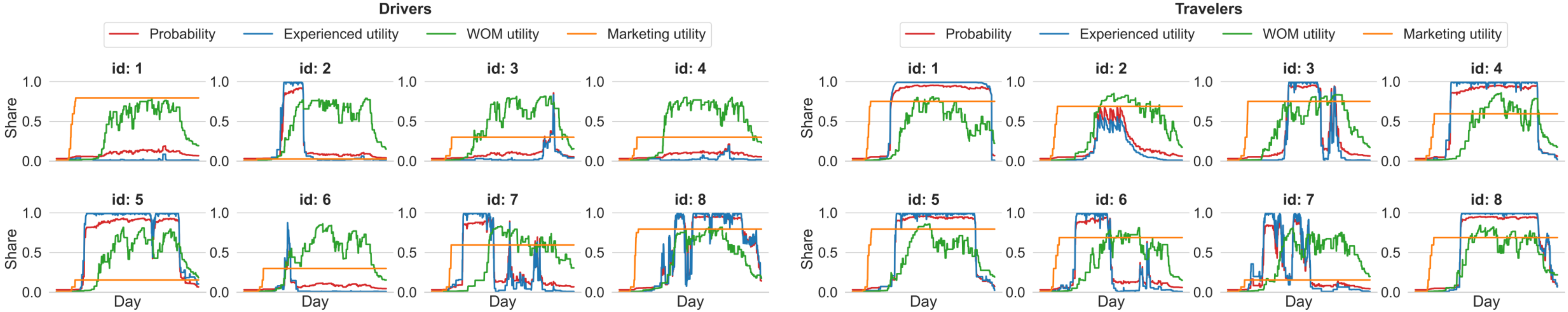


Fig 8. Evolution at the individual level.

Ghasemi, F. Kucharski, R., Modelling the Rise and Fall of Two-Sided Mobility Markets with Microsimulation. *Transportation Research Board (TRB 2023) 102nd Annual Meeting*, January 8–12, 2023, Washington, D.C – USA

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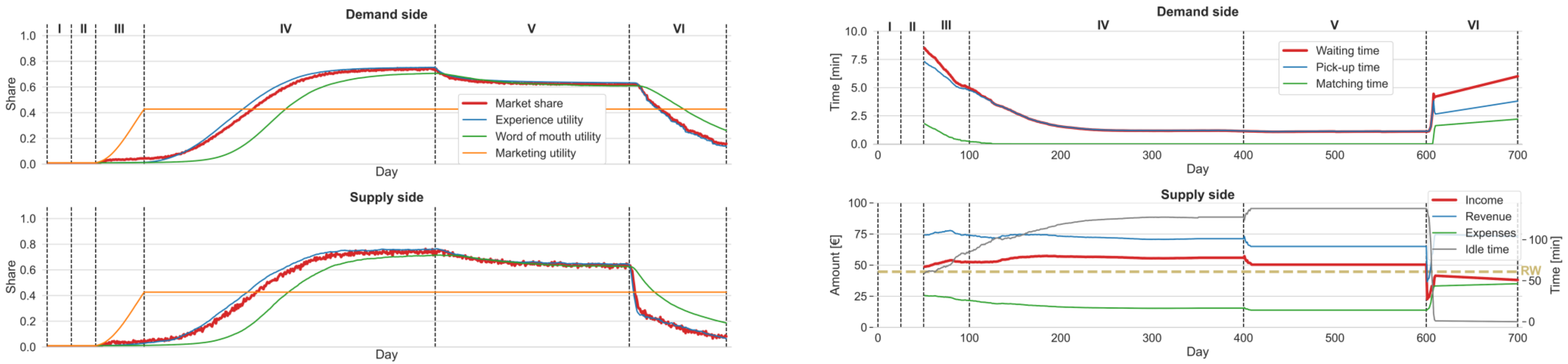


Fig 8. Evolution at the aggregated level.

Ghasemi, F. Kucharski, R., Modelling the Rise and Fall of Two-sided Markets. *The 23rd International Conference on Autonomous Agents and Multi-Agent Systems* (*AAMAS 2024*) , May 6–10, 2024, Auckland – New Zealand

Amsterdam Case Study on the Road Network

Fig 10. Agents’ distribution on Amsterdam road network on different days of simulation

Competition in Two-sided Mobility Market

Ride-sourcing platforms compete over **common** pool of passengers and drivers. The competition can lead to several equilibriums in the market depending on the **platforms' strategies**.

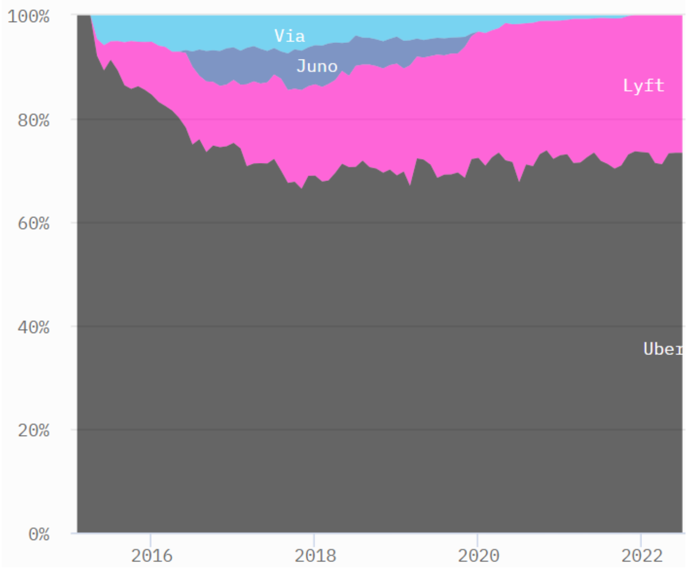


Fig 11. Platforms' market share in the ride-sourcing market of USA (toddwschneider.com). The competition in NYC has lead to market sharing (so far).

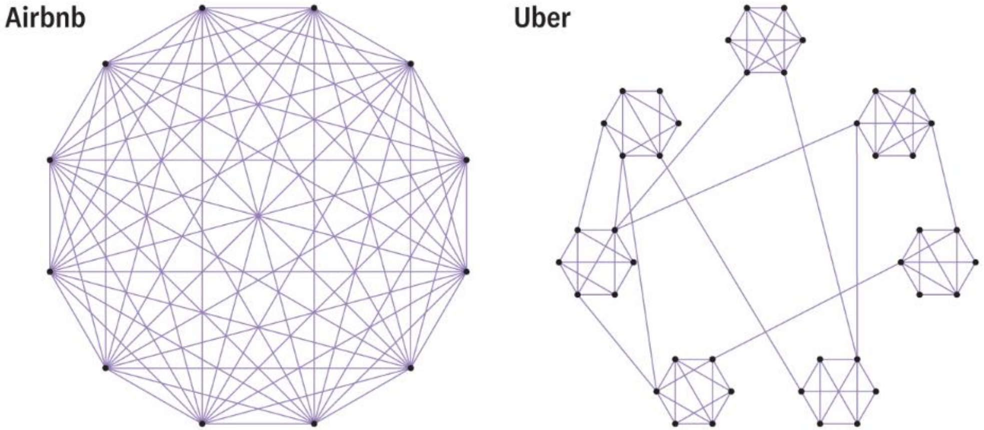
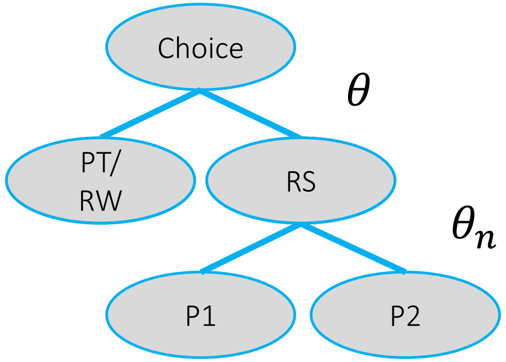


Fig 12. Airbnb and Uber networks (Zhu et al., (2019)). Uber has city-wide (weak) network while Airbnb has global (strong) network. This makes Uber extremely vulnerable to competition.

Choice Modelling (Nested logit)

I build on **WP1** and study the competition and the possible equilibria in ride-sourcing market. In particular, we implement nested logit model for the agents' participation choice. The correlation inside the nest is calculated as: $\rho = 1 - \frac{\theta_n}{\theta}$.



$$P_{i,t}^{k/n} = \frac{exp(\frac{U_{i,t}^{k}}{\theta_n})}{\sum_{k' \in K} exp(\frac{U_{i,t}^{k'}}{\theta_n})}$$

$$W_{i,t}^{n} = \theta_n . log\left(\sum_{k' \in n} \exp\left(\frac{U_{i,t}^{k'}}{\theta_n}\right)\right)$$

$$P_{i,t}^{n} = \frac{exp(\frac{W_{i,t}^{n}}{\theta})}{\sum_{n' \in N} exp(\frac{W_{i,t}^{n}}{\theta})}$$

$$P_{i,t}^{k} = P_{i,t}^{k/n} \, . \, P_{i,t}^{n}$$

The correlation inside the nest is calculated as: $\rho = 1 - \frac{\theta_n}{\theta}$.

Amsterdam case study with a pool of 2000 travelers and 200 drivers

Fig 13. Choice correlation affect on the platform market share in duopoly market. The dashed line indicates the platform market share in monopoly market.

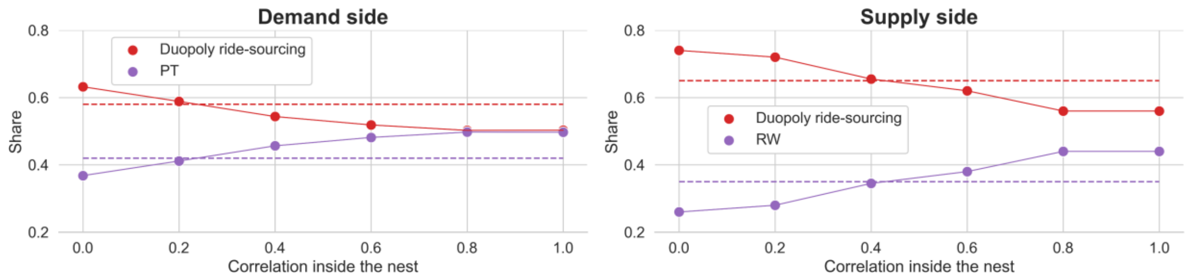


Fig 14. There are two strategies that platforms can take. Strategy A: 40% discount on the first 200 days after launch with fixed 10% commission rate. . Strategy B: 80% discount on the first 200 days after launch with fixed 10% commission rate.

Scenario 1:

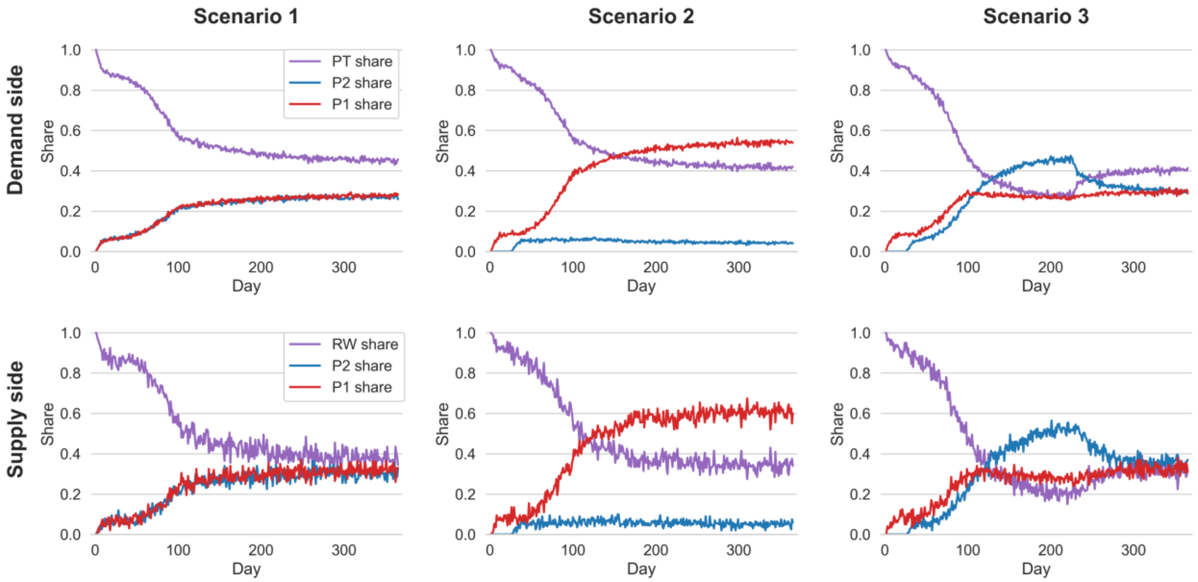
- ➢ Both platforms follow strategy A
- ➢ Both platforms enter the market on the same day

Scenario 2:

- ➢ Both platforms follow strategy A
- ➢ Platform 2 (blue) enters the market later

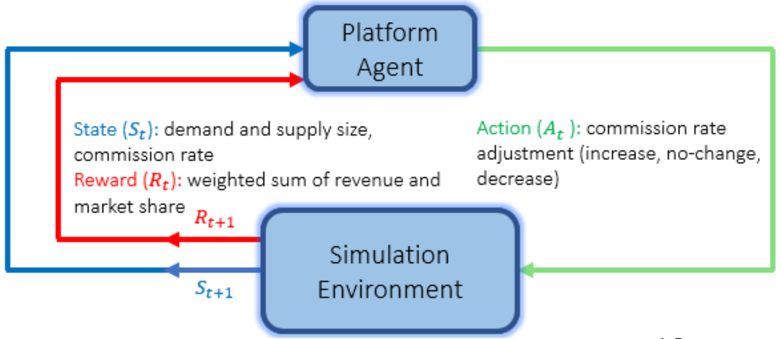
Scenario 3:

- ➢ Platform 1 adopts strategy A
- ➢ Platform 2 adopts strategy B and enters the market later



Ghasemi, F. Drabicki, A. Kucharski, R., Dynamics of the Ride-Sourcing Market: A Coevolutionary Model of Competition between Two-Sided Mobility Platforms. *11th symposium of the European Association for Research in Transportation (hEART 2023)*, September 6-8, 2023 , Zurich – Switzerland

RL Integration into MoMaS



15. Reinforcement learning diagram

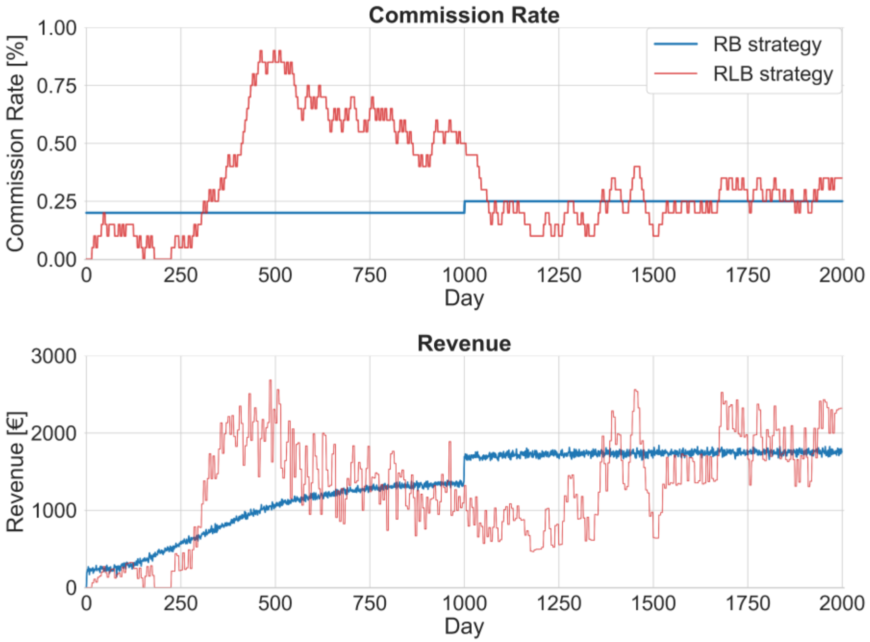


Fig 16. RL-based strategy vs Rule-based strategy

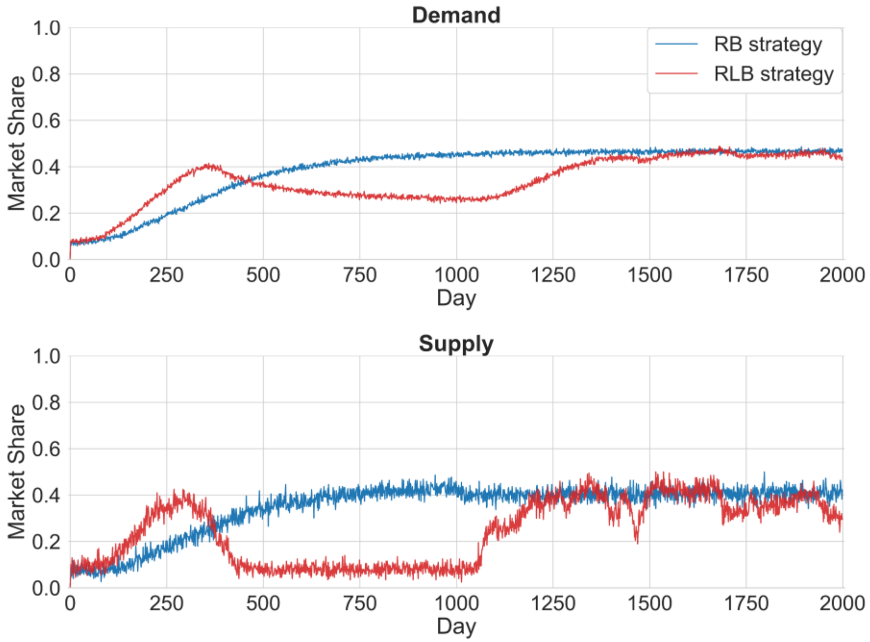


Fig 17. RL-based strategy vs Rule-based strategy

RL Integration into MoMaS

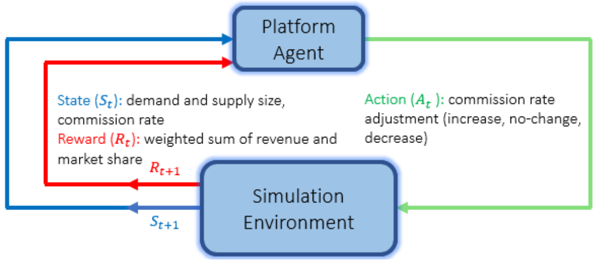


Fig 15. Reinforcement learning diagram

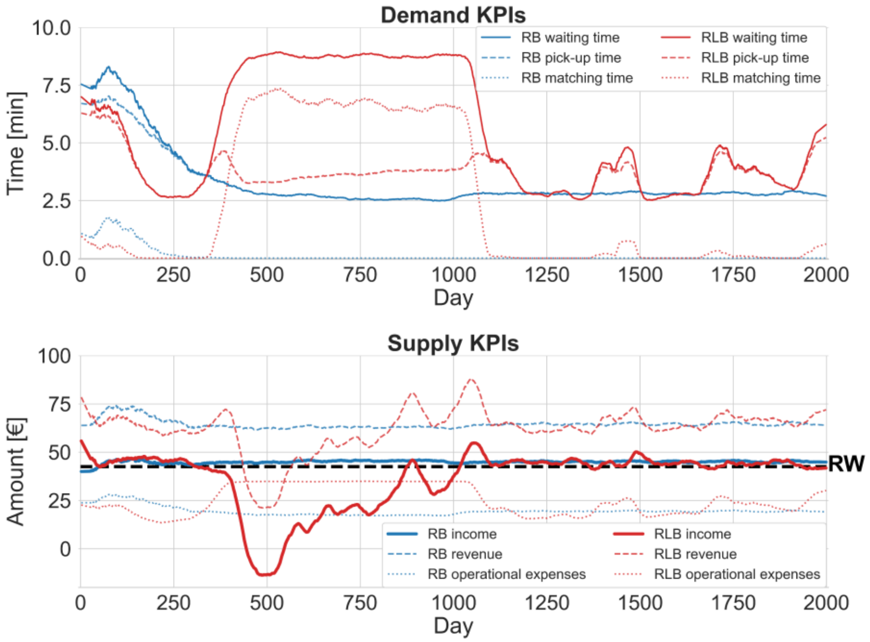


Fig 18. RL-based strategy vs Rule-based strategy

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Questions?

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