



HAL
open science

Trip-based MFD Model With Tradable Credit Scheme: Investigating Modal Equilibrium

Louis Balzer, Ludovic Leclercq

► **To cite this version:**

Louis Balzer, Ludovic Leclercq. Trip-based MFD Model With Tradable Credit Scheme: Investigating Modal Equilibrium. TRB2022, 2022, Washington DC, United States. hal-04662260

HAL Id: hal-04662260

<https://hal.science/hal-04662260v1>

Submitted on 25 Jul 2024

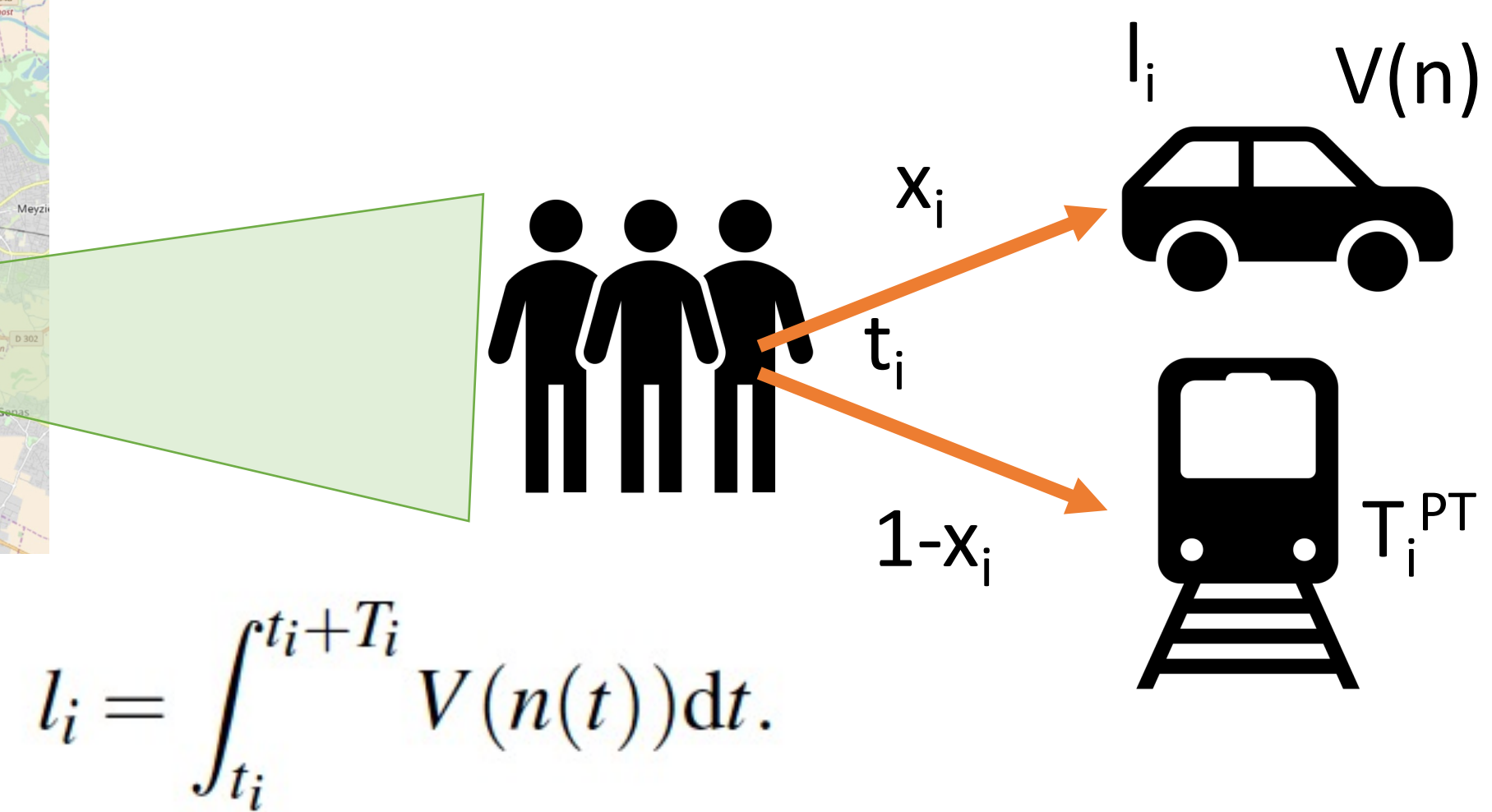
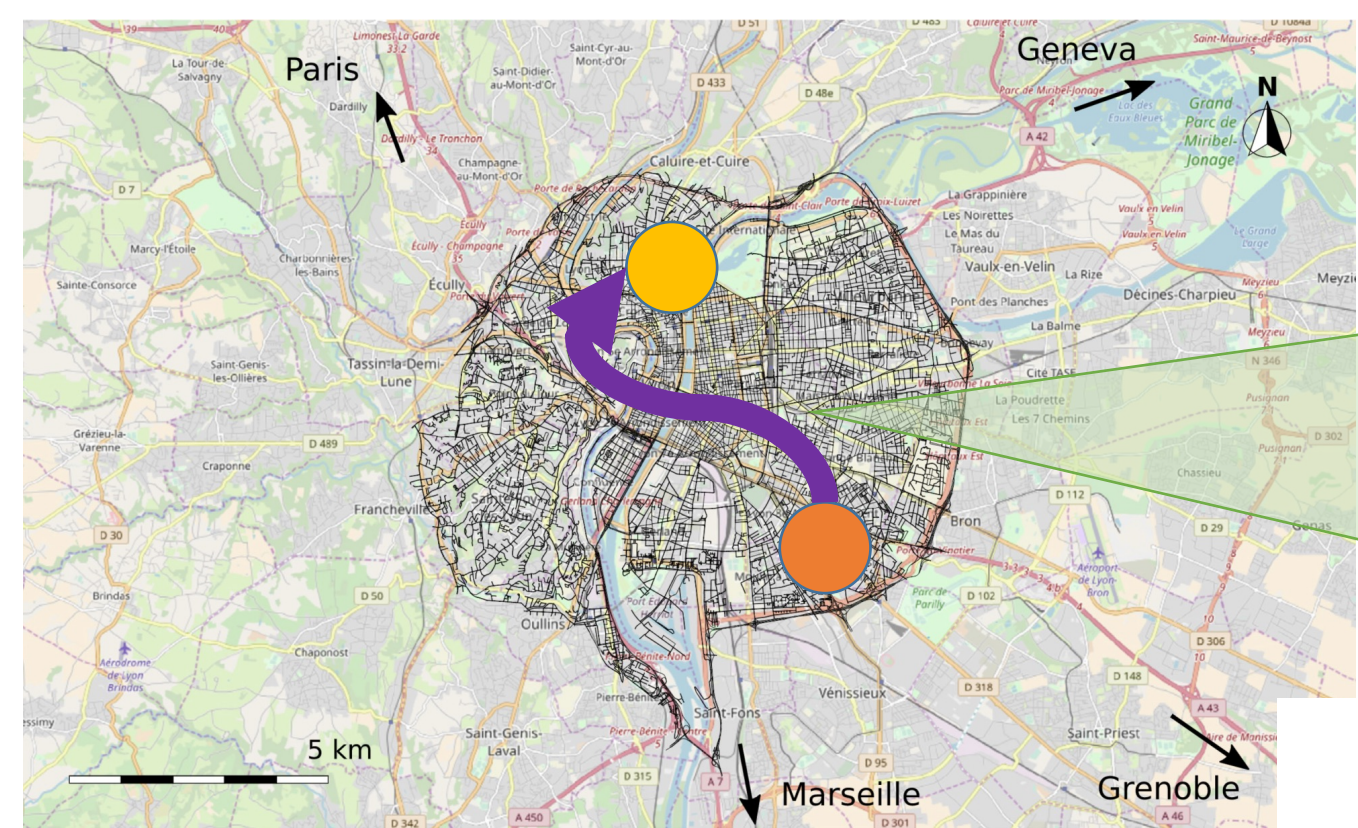
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Motivation

- ✘ We implement a Tradable Credit Scheme (TCS) to foster modal shift from personal cars to public transportation (PT) to reduce congestion and pollution during the 7:00-10:00 morning commute in Lyon.
- ✘ We use the trip-based MFD framework to represent the congestion. It accounts for the departure time and trip length of each traveler. The congestion dynamic is represented by the uniform mean speed on the network.

Model description and assumptions



- ✘ For each group i , departure time t_i and travel distance l_i are fixed.
- ✘ Degree of freedom is car share x_i . The rest rides PT. PT travel time T_i^{PT} depends on the PT operations (timetables).
- ✘ City model: one reservoir with trip-based MFD.
- ✘ Each user gets κ credits, needs τ credits to take the car, 0 for the PT, and can trade them on a market.
- ✘ Offer and demand determine credit price p .

An iterative quadratic optimization based on travel times linearization

- ✘ Travel costs perception

$$\begin{cases} C_{i,car} = \alpha T_i(\mathbf{x}) + \tau p; \\ C_{i,PT} = \alpha T_{i,PT}, \end{cases}$$

- ✘ Logit-based decision model

$$\psi_i(\mathbf{x}, p) = \frac{e^{-\theta C_{i,car}}}{e^{-\theta C_{i,car}} + e^{-\theta C_{i,PT}}}$$

$$\mathbf{x} = \psi(\mathbf{x}, p);$$

- ✘ Modal equilibrium

$$\begin{aligned} \tau \sum_{i=1}^N x_i &\leq N\kappa; \\ x_i &\geq 0 \quad \forall i; \\ x_i &\leq 1 \quad \forall i; \\ p &\geq 0, \end{aligned}$$

- ✘ QP formulation

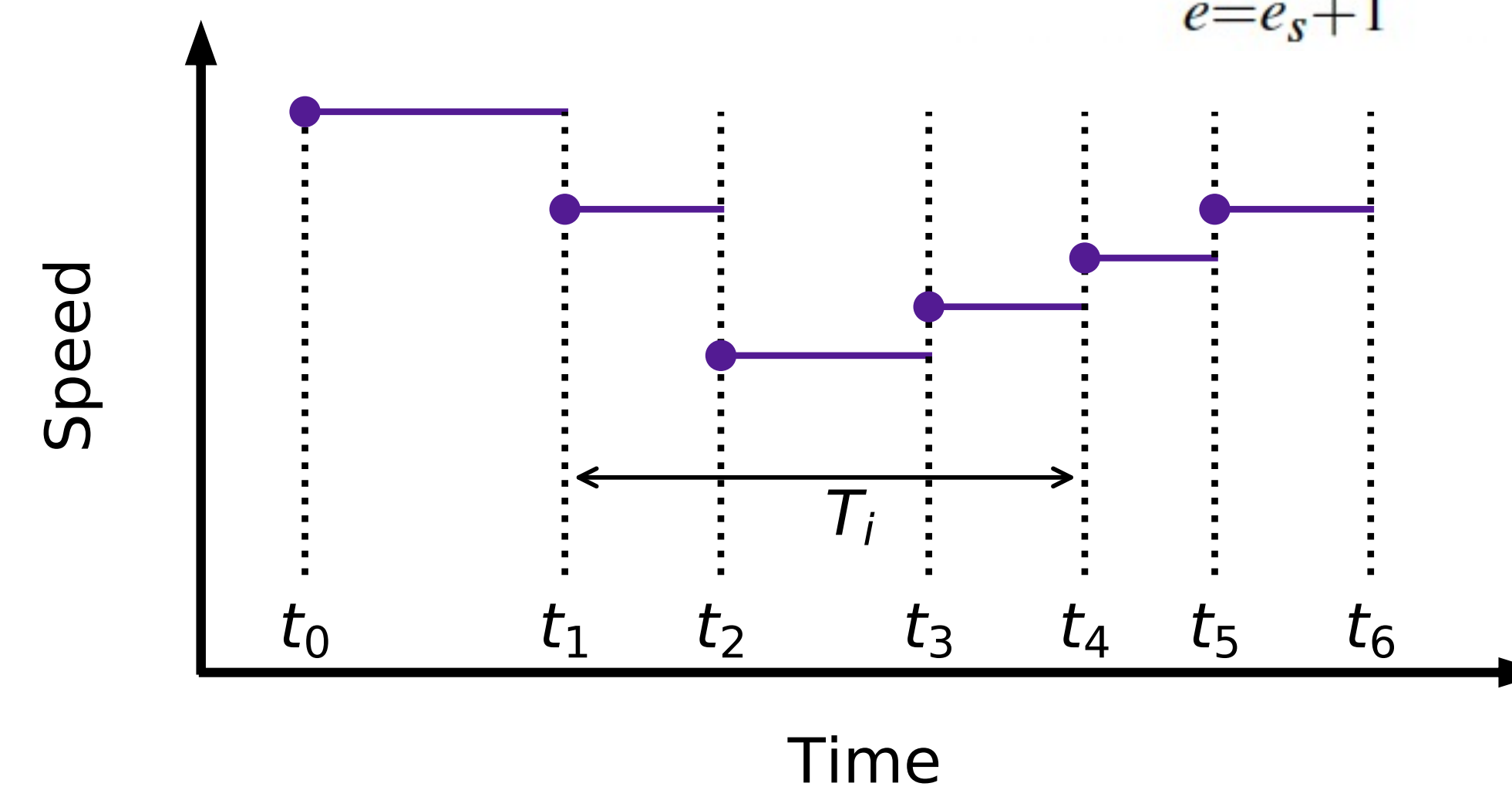
$$J = \frac{1}{2} \left\| (\tilde{\nabla} \psi - \mathbf{I}_x) \cdot \Delta \tilde{\mathbf{x}} + \psi_0 - \mathbf{I}_x \cdot \tilde{\mathbf{x}}_0 \right\|_2^2 + \frac{1}{2} \eta p^2,$$

- ✘ Travel time linearization

$$T_i = T_{0,i} + \nabla \mathbf{T}_i \cdot \Delta \mathbf{x} + o(\Delta \mathbf{x}).$$

- ✘ Split between events

$$\nabla \mathbf{T}_i = \sum_{e=e_s+1}^{e_e} \nabla \mathbf{T}_e.$$



- ✘ Differentiate event types

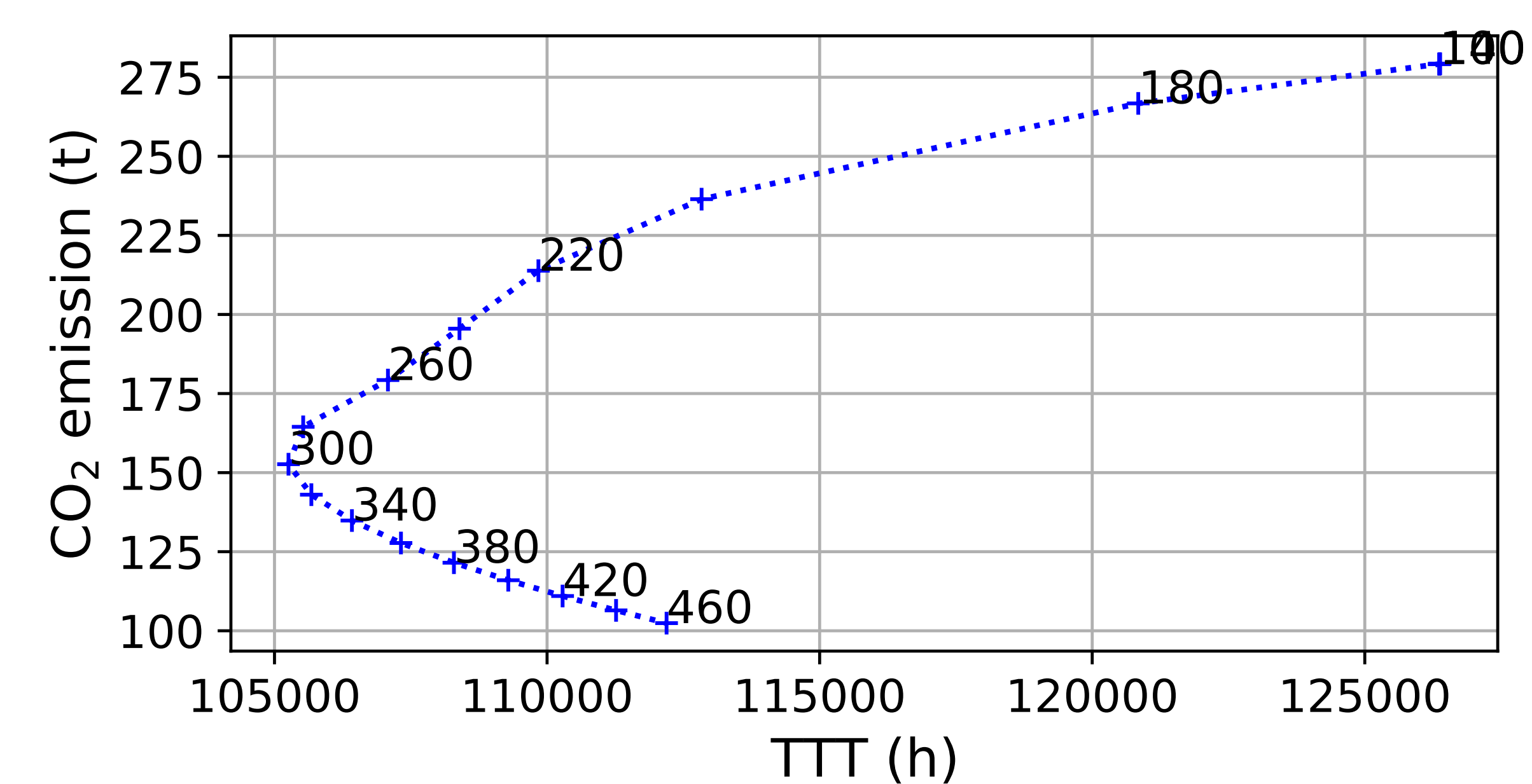
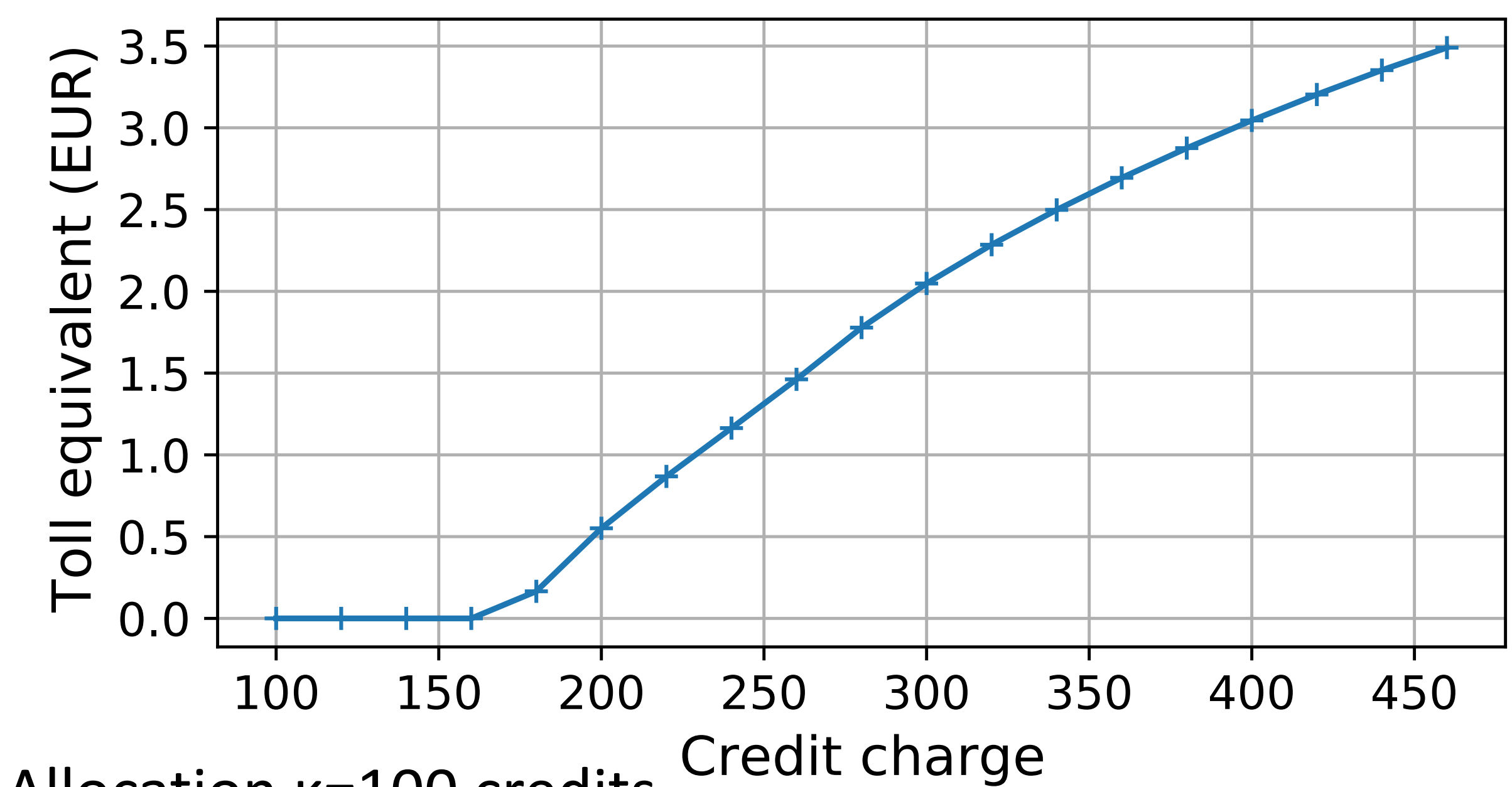
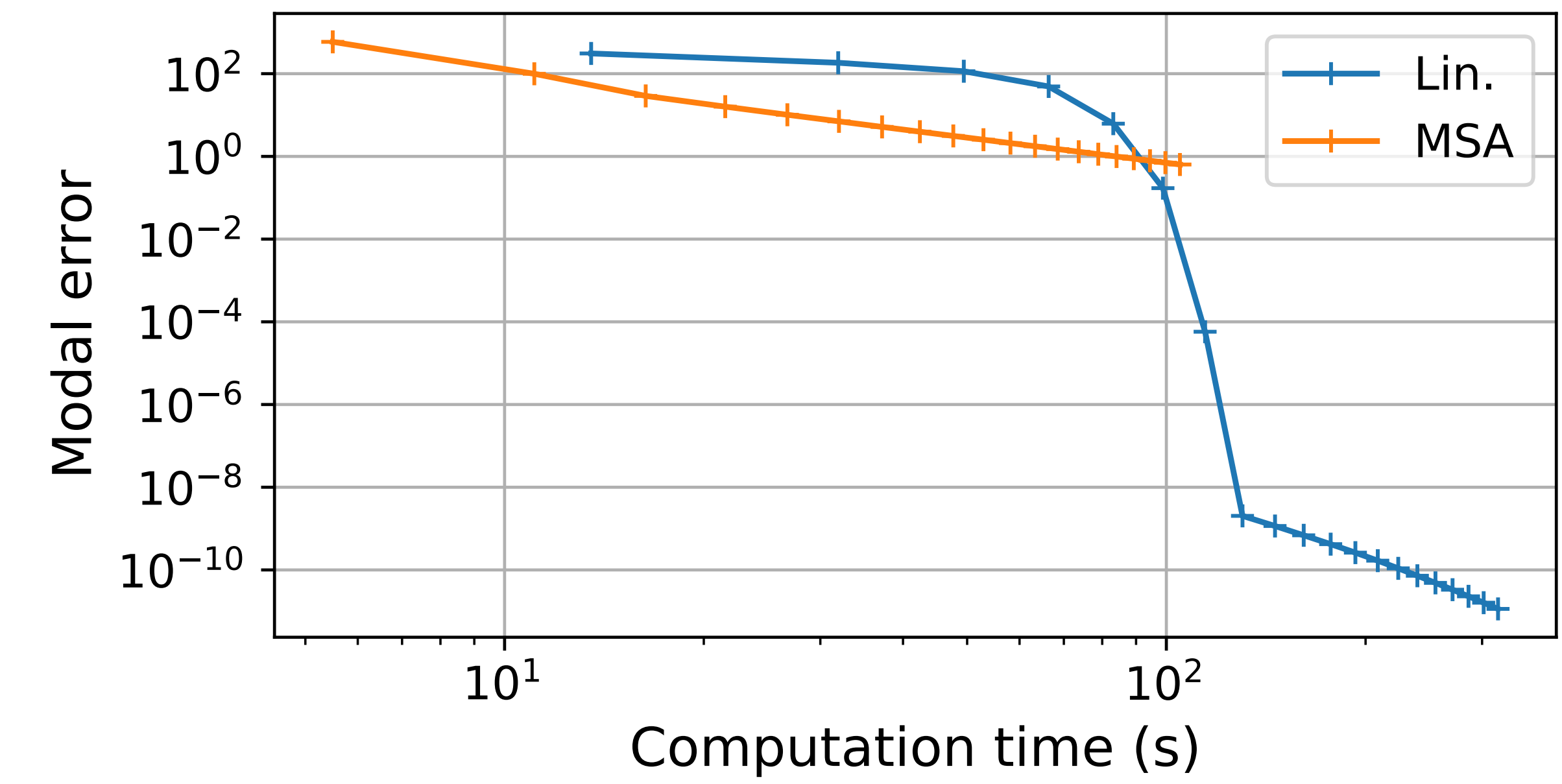
- ✘ Entry-entry $\nabla \mathbf{T}_e = 0.$

- ✘ Exit-entry $\nabla \mathbf{T}_e = -\nabla \mathbf{t}_{e-1} = -\sum_{g=1}^{e-1} \nabla \mathbf{T}_g.$

- ✘ *-exit

$$\nabla \mathbf{T}_e = -\frac{1}{V_e} \left(T_e \nabla V_e + \sum_{g=e_{i,s}+1}^{e-1} \nabla \mathbf{T}_g V_g + T_g \nabla V_g \right).$$

Results



Conclusion

- ✘ TCS improves total travel time by about 15% and carbon emission by around 45%.
- ✘ From a methodological point of view, iterative quadratic optimization based on travel times linearization reaches better precision than MSA.