SUM Lab Annual Research Report Summary

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Sustainable Urban Multimodal Mobility

Research Themes, Projects, and PhD students

Three themes are extensively explored in the SUM Lab associated with running and upcoming projects.

Climate Change, Sustainable Transport, and Infrastructure:

Transport networks (from infrastructure to operations) adaptation against the impacts of climate change are at the core of this theme of research. First and foremost, reliable and robust forecasting tools are required to identify the vulnerabilities of these networks. Nirmal Sitaldin (Link) is developing algorithms to identify these climate related events due to different factors as well as modelling the propagation of events and their associated gravities through the Dutch road network with the support of road infrastructure authorities (direct funding from **Rijkswaterstaat**). Short-, medium- and long-term recourse actions are investigated, and contingency measures are introduced.

Efficient spatial usage of the current transport infrastructure is a key to sustainable cities. Cities' borders cannot expand forever. Nature needs protection more than ever given the pace at which the environment is affected by urban developments. **XCARCITY** (Link), NWO perspectief, develops realistic digital replicas of car-low areas in Amsterdam, Almere, and Rotterdam. We develop digital twins to study how people use different smart mobility services. Currently four PhD candidates and one open postdoc position are associated with this project in the SUM lab. Nourhan Shokry (Link) works on dynamic usage of road infrastructure and designing passenger-oriented multi-modal travel options to promote car-low cities' mobility solutions. Jyotsna Singh (Link) works on developing multi-modal multi-objective optimization to link car-low/car-free areas with already existing transport network. Mohammd Jafari's (Link) PhD is dedicated to "sensor network design for strategic multi-modal transportation service planning". He works on the optimal location planning for sensors within a multi-objective framework. Azarakhsh Salem works on co-designing future mobility systems for the living labs. The open postdoc position is associated with extending the digital twin platform for three use cases.

Multi-Modality and Choice-Driven Trip Design, Real-Time Decisions for Passenger Mobility, and City Logistics:

This theme is dedicated to real-time operations and designing multi-modal and choice-driven service networks.

SUM project (Horizon Europe, Link) aims to facilitate the transformation of mobility in 15 European cities by 2026 and in 30 European cities by 2030. This transformation involves the integration of new shared mobility modes with public transport, focusing on innovation, interconnectivity, environmental sustainability, safety, resilience and replicability. Jingyi (Rina) Cheng's (Link) PhD research is to develop a real-time and adaptive demand forecasting algorithm for the near-future on-

demand New Shared Mobility service by identifying the complex dependencies across multimodal mobility service networks, next to the spatiotemporal patterns and sub-regional semantic correlations. Yimeng Zhang's (Link) postdoc position is focused on optimizing services provided by public transport and on-demand shared mobility systems while considering passengers' preferences by extending choice-based supply and demand steering models.

SINERGI project (Link) proposes a comprehensive solution framework for designing and operating sustainable city-logistics enabling real-time management and strategic planning of efficient and rider-friendly delivery services. SINERGI combines real-time and historical data (available through industrial partners in Europe and in Asia) with model-based scenario developments. Scientific challenges include (1) smart parking/mini-hubs allocation to efficiently use available urban space, (2) measuring behavior of riders to influence their behavior and (3) designing tailored services given urban constraints and real-time data on urban space availability, riders behaviour, fleet planning, matching, and dispatching. Kuldeep Kavta's (Link) postdoc position is associated with the behavioral modelling of riders and customers of meal delivery platforms of our partners in Europe, China and Singapore. Dongyang Xia's (Link) postdoc position is dedicated to real-time and choice-based routing and matching of the riders.

SUMMALab (NWO funded project, Link) provides substantiated and practice-oriented advice on setting up and evaluation of experiments of mobility systems in several living labs in the Netherlands. Koen de Clercq's (Link) PhD focuses on developing a transport model incorporating multiple transport modes using different behavioral models and network fundamental diagrams (super networks).

Mahsa Farhani's (Link) PhD research is dedicated to choice-driven service network design leveraging on the mathematical properties of Random Regret Models vis-à-vis Utility Maximization Theory to capitalize of inherited correlations between substitute travel options. The developed behavioral framework coupled with assortment optimization is then applied for operationalizing and rebalancing micro-mobility services.

Electrification, Innovative Transport Solutions under Uncertainty

In **V2G-QUESTS** we aim to provide clear guidelines on how to deploy V2G solutions that are equitable (used and accessed by all) and therefore produce a higher impact on the power grid balancing. The project integrates social sciences, geography, and legal aspects into engineering, management, and computer science. The project focuses on three case study districts in Aveiro (Portugal), Utrecht (The Netherlands), and Tartu (Estonia). V2G-QUESTS creates inclusive positive energy districts (PEDs) by empowering/emancipating/strengthening the power-balancing capacity of private and shared electric vehicles (EVs) in thus far EV-poor areas. Choice-based scheduling and service planning models under uncertainty are developed. A postdoc position is open for 2024 related to this project.

metaCCAZE accelerates the user-centred deployment of smart systems and services that combine electric automated and connected mobility and related infrastructure across European cities. metaCCAZE organizes a series of MetaDesign activities with multi-sector stakeholders and different population groups to develop metadesigned shared zero-emission mobility use cases, collaborative business, and governance models. A toolkit called MetaInnovations, is developed consisting of six

main smart technologies. MetaInnovations are pioneered in passenger and freight services (public transport, on-demand minibuses, bike sharing, deliveries) and related infrastructure (mobility and logistics hubs, traffic management centres, charging infrastructure) and widely demonstrated in four trailblazer cities (**Amsterdam**, Munich, Limassol, Tampere). Successful use cases, MetaInnovations and MetaServices are transferred, implemented, and demonstrated in 6 follower cities. There will be two open PhD and one postdoc positions in 2024.

Regarding the "**new and technological transport solutions**", Sara Momen's (Link) PhD research focuses on electrification and synchronization of bus network with e-mopeds. Through tailored robust optimization, uncertainty around the battery lifetimes and reliability of integrated networks are modelled. Dongyang Xia's (Link) PhD thesis investigates design and operationalization of autonomous and modularized bus systems. He investigates the integrated timetable coordination, vehicle scheduling and fleet management of these modularized bus network for which the capacity is dynamically managed (data-driven distributionally robust optimization). He extends the model to a multi-modal network. Zhuotong (Reena) Bai (Link) woks on dynamic demand responsive mobility services with enroute transfer using Markov decision processes.

Research Outputs in 2023:

Journal publications:

1. S. Xanthopoulos, M. Tuin, Sh. Sharif Azadeh, G. Correia, N. van Oort, M. Snelder. Optimization of the Location and Capacity of Shared Multimodal Mobility Hubs to Maximize Travel Utility in Urban Areas. Transportation Research Part A: Policy and Practice. (2023). In Press.

2. M. Lu, X. Yan, Sh. Sharif Azadeh, P. Wang. An adaptive agent-based approach for instant delivery order dispatching: incorporating task buffering and dynamic batching strategies. (2023). International Journal of Transportation Science and Technology.

3. Sh. Sharif Azadeh, R. Spliet, N. Agatz, M. Savelsbergh. Editorial Note: Supply and Demand Interplay in Transport and Logistics. Transportation Science. (2023). Link

4. R. Guoa, S. Bhatnagara, W. Guanb, M. Vallatia, Sh. Sharif Azadeh. Transportmetrica A: Transport Science. Operationalizing Modular Autonomous Customized Buses based on Different Demand Prediction Scenarios. (2023). Link

5. Sh. Sharif Azadeh, N. Aydin. Editorial Note: Data-driven optimization for transport and logistics systems. EURO Journal on Transportation and Logistics. (2023). Link

6. D. Xia, J. Ma, Sh. Sharif Azadeh, W. Zhanga. Data-driven distributionally robust optimization for the timetabling and dynamic-capacity allocation problem of modular vehicles in automated bus systems. Transportation Research Part C: Emerging Technologies. (2023). Link

7. H. Akyüz, R. Dekker, Sh. Sharif Azadeh. Real-time transportation planning in intermodal networks under disturbances. Transportation Research Part E: Logistics and Transportation Review . (2023). Link .

8. Zhang Y, Negenborn R R, Atasoy B. Synchromodal freight transport re-planning under service time uncertainty: An online model-assisted reinforcement learning. Transportation Research Part C: Emerging Technologies (2023) Link

9. Mehrabani, Jakob Erdmann, Luca Sgambi, Seyedehsan Seyedabrishami & Maaike Snelder. A multiclass simulation-based dynamic traffic assignment model for mixed traffic flow of connected and autonomous vehicles and human-driven vehicles, Transportmetrica A: Transport Science. (2023) Link

10. L Brederode, A Pel, L Wismans, B Rijksen, S Hoogendoorn. Travel demand matrix estimation for strategic road traffic assignment models with strict capacity constraints and residual queues. Transportation research part B: methodological. (2023). Link

11. L. Brederodea, L. Gerards, L. Wismansb, A. Pel, S. Hoogendoorn Extension of a static into a semi-dynamic traffic assignmentmodel with strict capacity constraints. Transportmetrica A: Transport Science (2023) Link

12. Z. Eftekhar , A. Pel , and H. van Lint. Effects of Periodic Location Update Polling Interval on the Reconstructed Origin–Destination Matrix: A Dutch Case Study Using a Data-Driven Method. Transportation Research Record. (2023). Link

13. Z. Eftekhar , A. Pel , and H. van Lint. A Cluster Analysis of Temporal Patterns of Travel Production in the Netherlands: Dominant within-day and day-to-day patterns and their association with Urbanization Levels. European Journal of Transport and Infrastructure Research (2023) Link

14. Nadi, Al., Yorke-Smith, N., Snelder, M., van Lint, J.W.C., Tavasszy, L.A. Data-Driven Preference-Based Routing and Scheduling for Activity-Based Freight Transport. Transportation research Part C Emerging Technologies. (2023) Link

15. Zhou, H., Dorsman, J.L., Mandjes, M., Snelder, M. A tour based multimodal mode choice model for impact assessment of new mobility concepts and mobility as a service. Transportation. (2023). Link

16. Zhou, H. Dorsman, J.L, Mandjes, M., Snelder, M.. On the use of common random numbers in activity-based travel demand modeling for scenario comparison. Transportation Planning and Technology (2023) Link

17. Zhou, H., Dorsman, J.L., Mandjes, M., Snelder, M. Sustainable mobility strategies and their impact: a case study using a multimodal activity based model. Case Studies on Transport Policy. (2023). Link

18. R. Haoa, M. Liua,W.Ma, B. van Arem, M. Wang A flock-like two-dimensional cooperative vehicle formationmodel based on potential functions. (2023). Link

19. S. Calvert, B. van Arem, J. Lappin. Herd immunity for traffic safety in mixed automated traffic: what if cars could not crash!? (2023). Link

20. R. Hao, Y. Zhang, W. Ma, C. Yu, T. Sun, B. van Arem. Managing connected and automated vehicles with flexible routing at ‘‘lane-allocation-free’’ intersections. Transportation Research Part C: Emerging Technologies. (2023). Link

21. A. Vial , M. Salomons , W. Daamen , B. van Arem , S. Hoogendoorn-Lanser, S. Hoogendoorn. Prioritizing Cyclists at Signalized Intersections Using Observations from Connected Autonomous Vehicles. Transportation Research Record. (2023). Link

22. Y. Wang, H. Farah, R. Yu, S. Qiu, B. van Arem. Characterizing Behavioral Differences of Autonomous Vehicles and Human-Driven Vehicles at Signalized Intersections Based on Waymo Open Dataset. Transportation Research Record (2023). Link

23. P. Ashkrof, G. Correia, O. Cats, B. van Arem. On the Relocation Behavior of Ride-sourcing Drivers. Transportation Letters. (2023) Link

24. M. Oskina, H. Farah, P. Morsink, R. Happee, B. van Arem. Safety Assessment of the Interaction Between an Automated Vehicle and a Cyclist: A Controlled Field Test. Transportation Research Record. (2023). Link

Defended PhDs

Zhang Y- Flexible, Dynamic, and Collaborative Synchromodal Transport Planning Considering Preferences. Delft University of Technology.

Han Zhou– Impact Assessment of New Mobility Services using Accelerated Activity-Based Demand Modelling.

Salil Sharma - On-trip Behavior of Truck Drivers on Freeways: New mathematical models and control methods.