SYSTEM ANALYSIS OF ON-DEMAND MOBILITY SERVICE
A SYSTEM DYNAMICS STUDY IN THE CONTEXT OF SUSTAINABLE URBAN MOBILITY

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Uber and Lyft are creating more traffic and congestion instead of reducing it, according to a new report.

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**VISION OF A MODERN CITY**
TRANSFORMATION FROM A CAR CENTRIC- TO A MORE LIVABLE CITY

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Ride-Hailing Services Add To Traffic Congestion, Study Says

As ride-hailing booms in D.C., it’s not just eating into the taxi market — it’s increasing vehicle trips.

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The future of Lyft is more carpooling

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Does sharing cars really reduce car use?

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Nutzen von Carsharing für die Umwelt umstritten

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# AGENDA

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OBJECTIVES AND RESEARCH QUESTIONS

Research Questions

1. What are the effects of future On-Demand Mobility services on traffic, emissions and land use / consumption in the city of Munich?
2. What are the relevant influencing factors for the future development of On-Demand Mobility Services?
3. Under what conditions can On-Demand Mobility services help to improve traffic, emissions and land use / consumption in the city of Munich?

What forms of On-Demand Mobility are being considered?

How is Sustainable Urban Mobility being operationalized?
SUSTAINABLE URBAN MOBILITY. OPERATIONALIZATION IN THIS STUDY.

Sustainable urban Mobility

Traffic Flow and Average Speed
- Spatially and temporally aggregated average speed in the study area

\[ V_{Avg}(t) = \frac{\sum_{h=1}^{24} \sum_{i=1}^{n_h} V_{hi}}{\sum_{h=1}^{24} n_h} \]

Air pollutants and Greenhouse Gas Emissions
- Emission inventories for carbon dioxide (CO2), particulate matter (PM) and nitrogen oxides (NOx) based on the mileage of different vehicle classes:

\[ E_{I{Poll}} = \sum_{m=1}^{M} [FL_m \times EF_m] \]

Land use and Land Consumption
- Total area for parked vehicles in public spaces (On-Street Parking) in the city of Munich.

\[ A(t) = C(t) \times A_c(t) \times \omega \]
\[ C(t) = f\{Fb(t)\} \]

\( V_{Avg} \): Average Speed
\( n_h \): Number of trips per hour
\( FL \): Milage
\( EF \): Emission factor
\( C \): Number of Vehicles
\( A_c \): Space per Vehicle
\( \omega \): Number of Vehicle parking on-street
\( Fb \): Vehicle Ownership
\( A \): Space
\( E_{I{Poll}} \): Emission inventar
ON-DEMAND MOBILITY. SEGMENTATION AND TERMINOLOGY.

On-Demand Mobility

- Car Rental
  - Operator-Based
  - Peer-2-peer

- Car Sharing
  - Free-Floating
  - Station-Based
  - Peer-2-peer

- Car Pooling
  - Car Pooling
  - Van Pooling

- Ride Hailing
  - Traditional Taxi
  - Transport Network Companies (TNC’s)

- Ride Pooling
  - Shared Ride / Taxi
  - Micro Transit / Smart Shuttle

- Micro Mobility
  - Bike Sharing
  - Scooter Sharing
  - E-Scooter Sharing

Global Service Provider
- AlphaRent
- Europcar
- AVIS

Local Service Provider
- Atamo
- Europcar
- Hertz

Days / Hours / Minutes

On-Demand Mobility Services I Christian Assmann

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ON-DEMAND MOBILITY. SEGMENTATION AND TERMINOLOGY.

On-Demand Mobility

Services
- Car Rental
  - Operator-Based
  - Peer-to-peer
- Car Sharing
  - Free-Floating
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- Car Pooling
  - Car Pooling
  - Van Pooling
- Ride Hailing
  - Traditional Taxi
  - Transport Network Companies (TNC’s)
- Ride Pooling
  - Shared Ride / Taxi
  - Micro Transit / Smart Shuttle

Global Service Provider

Local Service Provider

Services
- Car Rental
- Car Sharing
- Car Pooling
- Ride Hailing
- Ride Pooling
- Micro Mobility

Days / Hours / Minutes

Hours / Minutes

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METHODS.
RESEARCH DESIGN.

- **Literature-Review**
  - Orientation in the research field / state of the art.
  - Identification of applied methods.
  - Market analysis of existing services in Munich.

- **Explorative - Qualitative Expert Study**
  - Consideration of different stakeholders / perspectives.
  - Identification of relevant parameters / system variables.

- **Qualitative and Quantitative System Model**
  - Identification of the variables and their dependencies
  - Use of causal loop diagrams (CLD’s) and stock and flow diagrams (SFD’s) to identify the mechanisms in the system
  - Quantitative system modeling on the basis of suitable data inputs and relevant future scenarios
  - Software: PowerSim (System Dynamics)

- **Preparation and Interpretation of the Results**
  - Evaluation and interpretation
  - Identification of different levers
  - Formulation of recommendations for action
HIGH-LEVEL SYSTEM MODEL OVERVIEW. ODM SYSTEM.

**System Input**
- Demography: Population, Age distribution, Education, Income
- City: Car ownership, density, Public transport capacity
- Technology: E-Mobility, Autonomous Driving
- Regulatory: Parking costs, Driving bans, City toll

**Mobility Demand / Attractivity Model**
- Attractivity of Transport Mode
- Temporal changes & rebound-effects

**ODM System Model**
- Traffic Performance (in person kilometers)
  - ODM
  - Cycling
  - Walking
  - Private Car
  - Public Transport

**Supply / ODM Service Simulation**
- Detours / empty trips / relocation
- Electrification share of fleets
- Occupation levels
- ...

**System Output**
- Space: On-street parking Space [m²]
- Emissions: CO₂, NOₓ, PM
- Traffic Flow: Average Speed

**Vehicle Kilometers Travelled**
(Total vehicle kilometers in the study area)

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SYSTEM MODEL RESULTS – EMISSIONS.

Qualitative & Quantitative System Modelling

- Development of a Causal-Loop-Diagram
- Development of a Stock-and-Flow-Diagram

Quantitative Scenario-Analysis

Application of three Future Scenarios

- Evolution / Revolution / Disruption

Variation of different Variables

- Substitution / Modal Shifts
- Additional kilometer effort ODM (detours, empty trips, relocation and service trips)
- Electrification of ODM vehicles (forecast share of BEV / PHEV in vehicle fleets)
- Impact of ODM on vehicle ownership (abolition of cars by using ODM services)

Scenario Results
RESULTS

Traffic
- Shifts / Substitution Effects of public transport, bicycle and pedestrian traffic
- Relocation, maintenance trips and service trips
- Empty trips between
- Higher occupancy rates than private Cars, even if the realization of “high” occupancy rates is problematic

In the scenarios examined, ODM generally does not lead to any traffic reduction

Improvement of the overall traffic impact only under highly optimistic assumptions

Emissions
- An increase in motorized traffic leads to increased emissions of air pollutants and greenhouse gas emissions
- Improved engine / exhaust technology leads to a significant reduction in NOx, PM and CO2 emissions
- High proportion of electrification ODM vehicles

The impact of ODM on emissions depends largely on substitution effects, the share of electrified vehicles and the corresponding mileage.

Space – On-Street Parking
- ODM vehicles are mainly parked in the public inner-city area
- Positive impact on private car ownership (different vehicle abolition rates simulated)
- Generally positive effect (strong supportive effect through regulation of private Cars)

In the scenarios examined, ODM leads to a reduction of the required parking space
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Recommendations for Action / Limitations of the Study

**Recommendations**

**Emissions**
- Increase in the proportion of electrification in ODM vehicle fleets (100% electrification of ODM fleets if possible)

**Traffic**
*The underlying substitution effects/ shifts in the modal share have a strong impact on the model results.*
- ODM Service characteristics close to Private Car (through suitable service characteristics)
- Regulation of the Private Car (e.g. through road pricing, or parking space management) in order to influence the attractiveness of the Private Car Usage and to support a mobility behavior change towards ODM.
- Differentiation in price between ODM and public transport is necessary in order to reduce substitution effects between public transport and ODM.

**Space**
- Examination of whether ODM vehicle fleets can partly also be parked on off-street parking areas in order to reduce land use in public spaces.

**Limitations of the Study**

**General limitations of the work**
- Difficult to compare the literature: large differences regarding the sustainability impacts (e.g. impact of Car Sharing FF on car ownership 0.3 - 17.0 vehicles (Hülsmann et al. (Share), 2018), Firnkorn et al., 2012))
- Expert interviews, in some cases, strongly influenced by their own subjective / expectations. A clear differentiation between realized effects and possible potential is necessary.
- Changes in mobility behavior / adoption of services due to current market penetration cannot be fully mapped

**Limitations System Model**
- Data basis (e.g. MiD; 2017 - household survey of residents of the city of Munich).
- Validation of system interrelationships (especially quantification of soft system elements).
- Validation of the assumptions / input variables.
- Unclear model usage (black box).
- Spatially aggregated model (large spatial differences to be expected in some cases).
THANK YOU FOR YOUR ATTENTION!

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