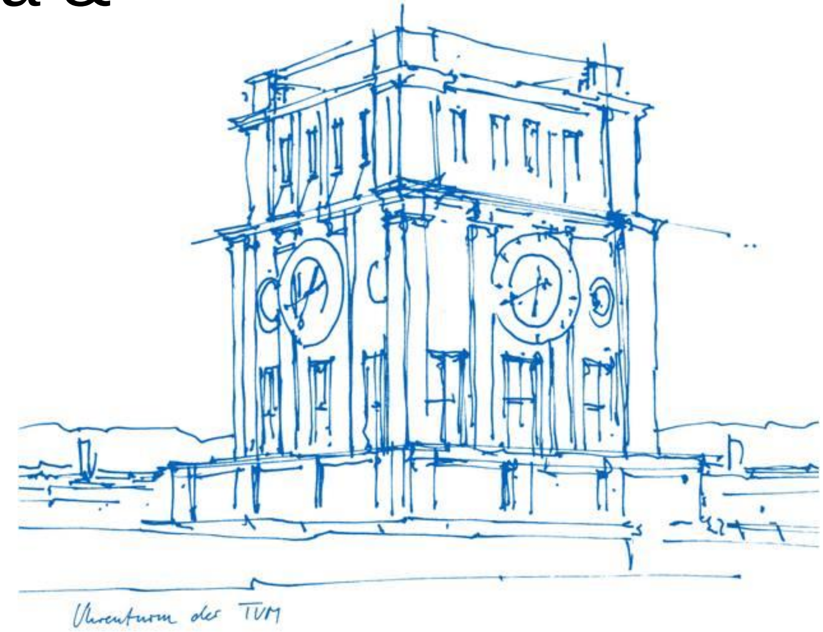
Professorship of Mobility Policy
TUM School of Social Sciences and Technology
Technische Universität München

Analysing the Impacts of the 9-Euro-Ticket on Mode Choice using GPS Panel Data & Discrete Choice Models

Friederike Beck
Santiago Álvarez-Ossorio Martínez
Klaus Bogenberger
Allister Loder



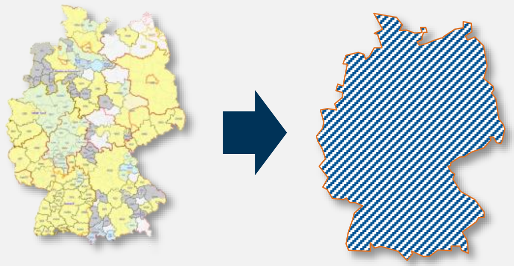
TRB, Washington, D.C.

January 7, 2025

TRBAM-25-02529

Measuring a Policy Intervention

Fare Innovation: The 9-Euro-Ticket



242.70 €

9 €

Data Processing & Methods

GPS

Results & Policy Implications

VTTS

75 %

Policy Assessment ?

Fare Innovation: The 9-Euro-Ticket

Crisis to Opportunity: Germany’s Transformative Fare Innovation

9-Euro-Ticket
A low-cost ticket for affordable public transportation (PT)

Fuel Tax Cut
A reduction in fuel taxes to lower transportation costs

Intervention Period
June, July & August 2022

Behavioral Change
Aim of inducing demand for sustainable transportation

Call for Inquiry: Uncertain Impact of FFPT on Travel Behavior

Diverse FFPT Policies: Variations in scope and context complicate drawing generalized conclusions.

Research Gap: Limited comparative and review studies on the impacts of FFPT policies. (Fearnley, 2013; Kębłowski, 2019)

Post-COVID-19 Surge: 60% of US urban networks applied temporary FFPT, with notable policies in Germany (€9 ticket) and Spain (fare-free trains). (Štraub et al., 2023)

Induced demand → FFPT leads to an overall rise in PT trips (Brand, 2008; Kębłowski, 2019; Cats et al., 2017; Straub & Jaroš, 2019; Hess, 2017)

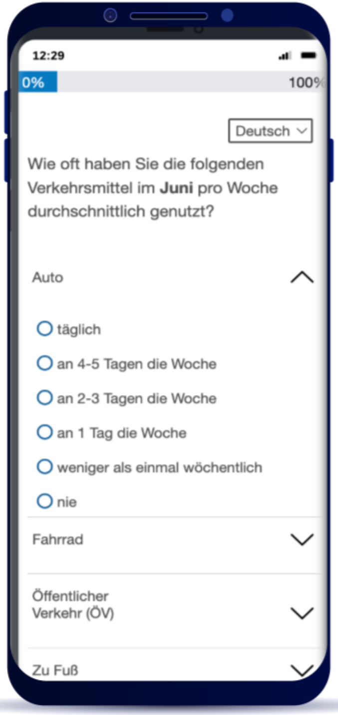
Limited substitution effects for motorized travel (Fearnley, 2013; Cats et al., 2017; Bull et al., 2021; Liebensteiner et al., 2024)

Window of Opportunity for Research

Window of Opportunity: „Mobilität.Leben“ Study

Smartphone-App

&



Survey

Passive to (Semi-) Passive Travel Diaries

Sensor data collection

- GPS-based coordinated
- Corresponding timestamp
- Motion sensor data

MOTIONTAG

Track detection → Mode imputation

Stack detection → Purpose imputation

Validation of travel diary via app

- Confirmation of stays/tracks
- Correction of transport mode
- Annotation/Correction of stay purpose
- Merging of consecutive tracks
- Removal of erroneously detected stays/tracks

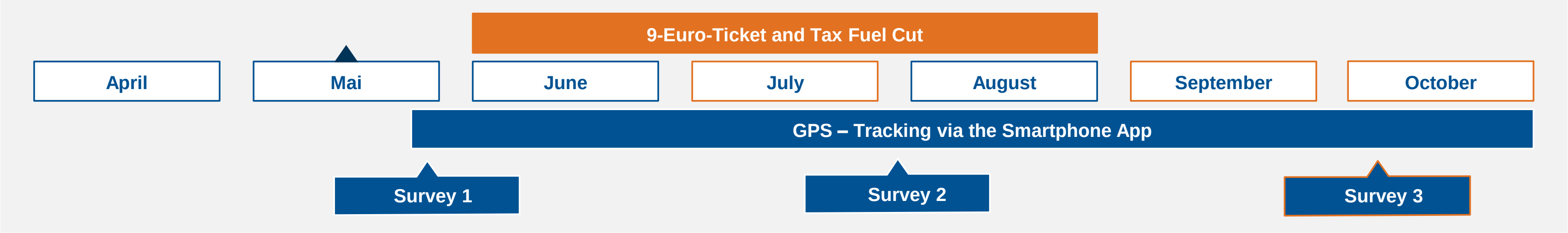
Dahmen el al. (2024)

A Rich but Challenging Data Source

A 3-month subset of the *Mobilität.Leben* panel data:

Intervention Period: Second month (July) of the 9-Euro-Ticket

Post-Intervention Period: September & October, 9-Euro-Ticket was no longer in effect



Total: 154,605 trips by 785 users processed for analysis.

How the Ticket Shapes Travel Decisions

? How did the German fare policy intervention of the 9-Euro-Ticket impact the Value of Travel Time Savings (VTTS) across various modes of transportation?

Defining the Choice Set: Essential data processing and filtering steps for using discrete choice modeling (Tsoleridis et al. 2022)

Estimating Weighted VTTS: Critical metric for project evaluation and policy appraisal.

Data Processing & Methods

Theory-Driven Modeling Approach

Discrete Choice Modeling (Hensher & Johnson, 1981; Ben-Akiva & Lerman, 2018)

- Statistical framework used to analyze and predict decision-making
- Individuals select one option from a finite set of alternatives
- Based on the behavioral theory of Random Utility Maximization (RUM)

	Stated Preference Data	GPS-Based Revealed Preference Data
+	• Control of experimental design • Includes non-existing alternatives • Cheap → Many responses per participant	• High amount of granular data at lower cost • Data generation is quasi-automatic • Observes all trips → "perfectly" accurate • Multiple-day data
–	• Behavioral incongruences and biases • Non-consequentiality of the choices?	• Noisy data • Heavy processing & expertise needed • Still not mature / validated enough?

Raw Tracks, Real Choices:
From GPS Data to Behavioral Models

Data on Non-Chosen Alternatives → **Data Enhancement** → **Validity & Quality Checks** → **Filtering Trips**

Data on Non-Chosen Modes: Including Alternatives

Data: Information on chosen (observed) trips

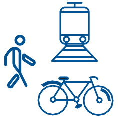
Challenge: Obtain data for non-chosen alternatives and their attributes

Generate: Travel times, access/egress and waiting times for chosen and non-chosen modes

Usage of APIs:

TomTom Routing API:

Provides travel times and distances based on typical conditions for that time of day and day of the week



OpenTripPlanner API:

Utilizes Munich's transportation network and real GTFS data. Data reflects scheduled services available on the exact day of each trip

Data Enhancement: Including Cost and Weather

User	Start time	Start/End Location	Chosen Mode	TT Bus
A	08:00	…	Bus	15 min

+

Cost Bus	TT car	Cost Car	TT Bike	Weather	…
2€	08:00	1.5€	8 min	Rainy	…

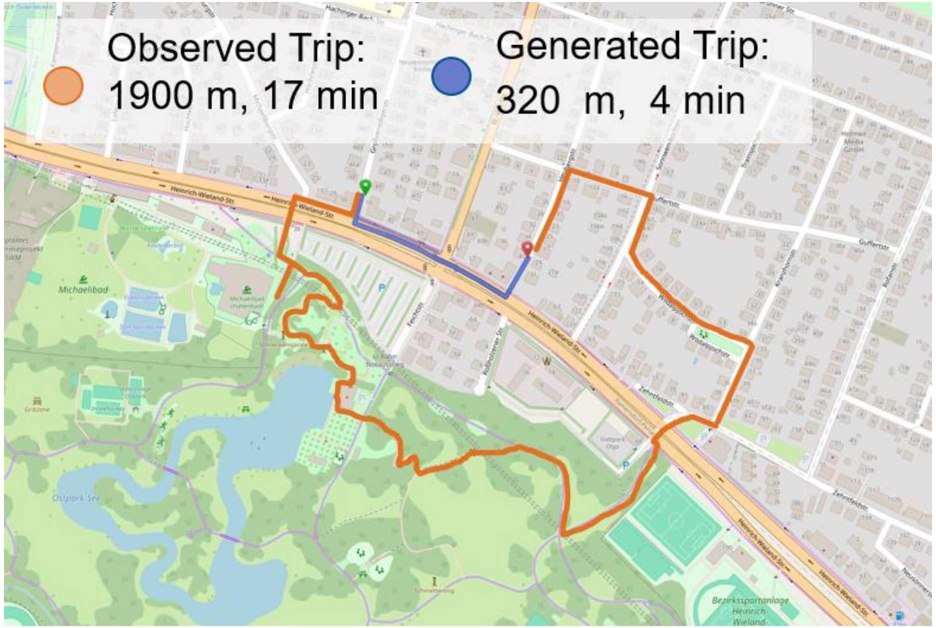
TomTom API & OpenTripPlanner API

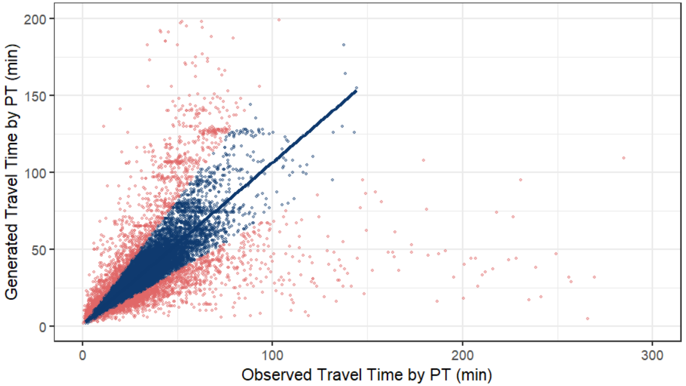
Data on Munich's transit authority and Survey Input

Data on from the German Weather Service (DWD)

More details in Dahmen et al. (2023)

Deviation Between Observed and Generated Trips





Filtering Method to Set the Choice Set Right

Short-distance urban mobility < 35 km

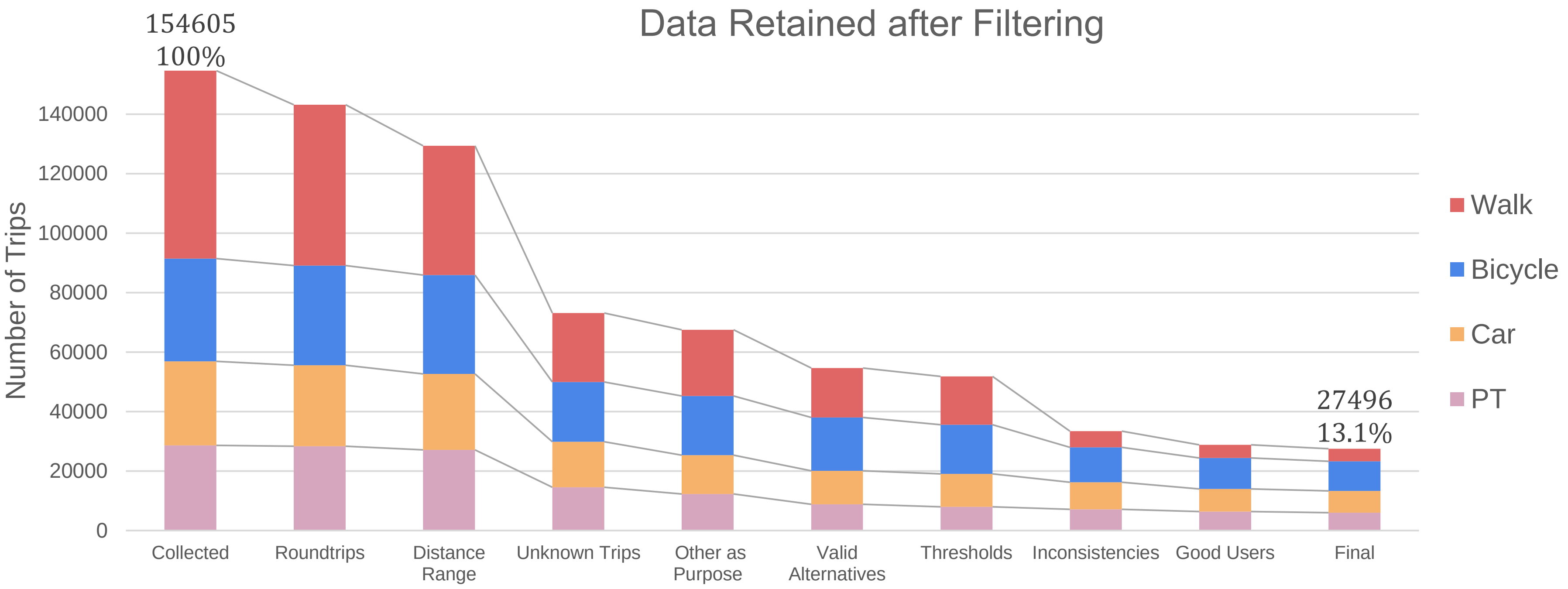
Standard Modes: Walk, Bike, Car, PT, Walk as access/egress mode

Purposeful Trips: Shopping, leisure, commutes, home

Filtering trips with a high deviation ratio

Exclusion of recreational and round trips

Prioritization of Data Quality Over Quantity



Modeling the 9-Euro-Tickets Impact

Estimation of two separate multinomial logit (MNL) models:

Intervention MNL

Post-Intervention MNL

→ Comparison of VTTS

Increased Robustness: Bootstrapping and weighting of VTTS

Control for Heteroscedasticity in the Choice Set: Scale for distance bands

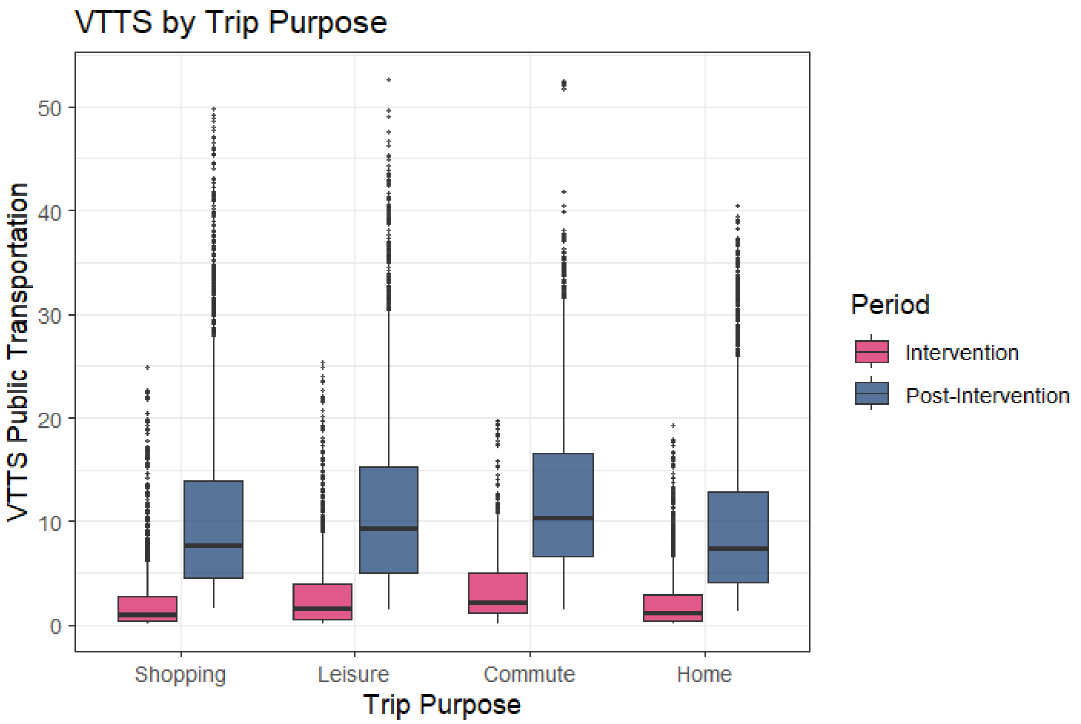
Key Challenge: Lack of consideration for individual preference heterogeneity

Results & Policy Implications

Particularly Strong Effects on the VTTS for PT

The Intervention Shifts VTTS:

- Walking ~1-2x
- Driving ~ 1-2x
- Cycling ~3-4x
- Public transportation ~3-5x



Appraisal Dilemma: Fare-Free Public Transportation

Traditional Approach:
Projected savings in travel time drive project appraisals and cost-benefit analysis

The Twist:
Lower VTTS → Long-term behavioral change
Lower VTTS → Decline in projected benefits?

The Big Question
Will (almost) fare-free innovations undermine future investments?

Future Research
- Improved understanding of behavioral effects for other fare policy interventions
- Improved understanding of the implications for transit agencies and funding

Key Insights for Effective Data Collection

Opportunity:
GPS-based RP data offers significant potential for policy assessment, enabling realistic insights and reducing certain biases present SP data.

Beyond Quantity:
Methods must advance to extract meaningful insights from noisy data, ensuring quality complements the growing data volume.

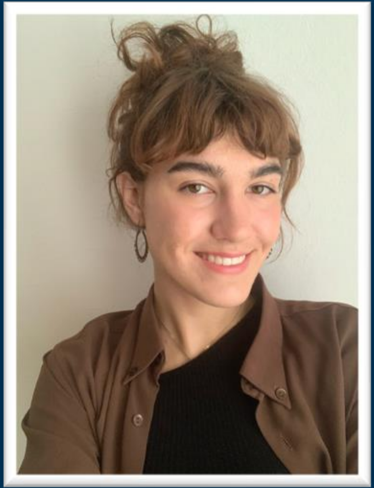
Purpose-Driven Data Collection:

- Fit for purpose
- Inherently validated and enriched
- Appropriate methods for processing and modeling

Thank You for Your Attention!

Download the Paper:

Stay in Touch!



Friederike Beck
Friederike.beck@tum.de

LinkedIn:

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Appendix

Validity and Quality Checks: Deviation Ratio (DR)

DR between Generated and Observed Trips:

$$DR_{distance} = \frac{|\,Distance_{observed} - Distance_{generated}|}{Distance_{generated}}$$

$$DR_{traveltime} = \frac{|\,TT_{observed} - TT_{generated}|}{TT_{generated}}$$

TABLE 1: Correlation and Deviation Ratios for Different Travel Modes

	Main Mode			
	Car	**PT**	**Bicycle**	**Walk**
Data quality *before* filtering for dev. ratio				
Correlation distance	0.95	0.89	0.96	0.74
Correlation travel time	0.73	0.17	0.62	0.50
Mean dev. ratio distance	0.23	0.17	0.20	0.39
Mean dev. ratio travel time	0.57	0.39	0.51	0.87
Maximum dev. ratio distance	51.28	18.88	73.29	139.65
Maximum dev. ratio travel time	92.22	123.53	117.35	233.85
Data quality *after* filtering for dev. ratio				
Correlation distance	0.97	0.97	0.98	0.96
Correlation travel time	0.92	0.90	0.92	0.90
Mean dev. ratio distance	0.11	0.11	0.11	0.14
Mean dev. ratio travel tim	0.28	0.16	0.25	0.26
Maximum dev. ratio distance	1.00	0.39	0.99	0.73
Maximum dev. ratio travel time	**1.00**	**0.39**	**1.00**	**0.73**

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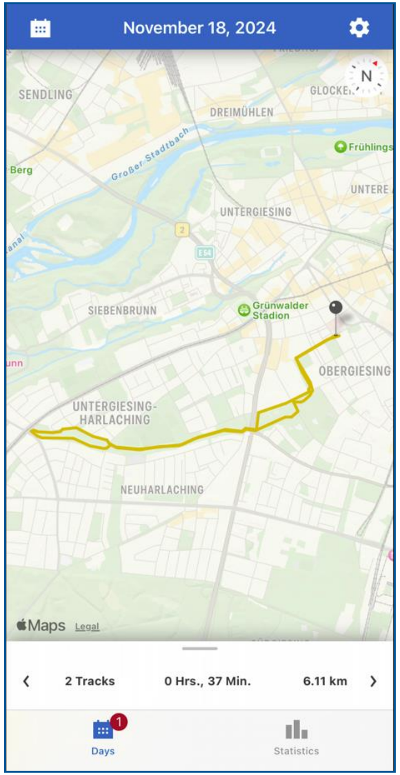
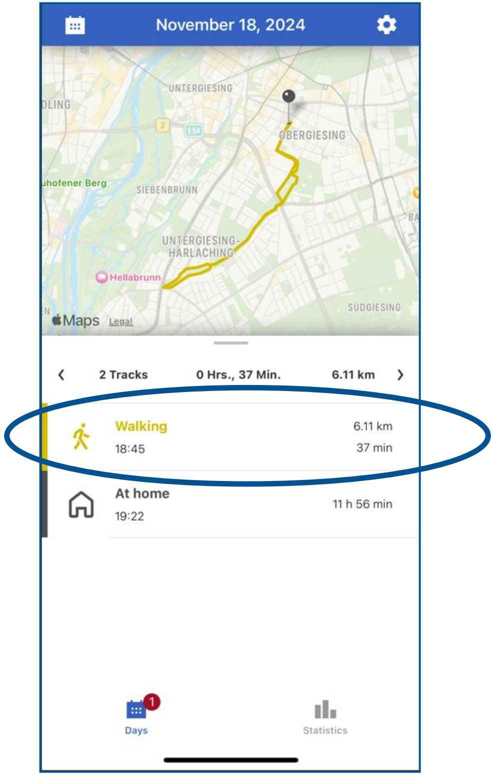
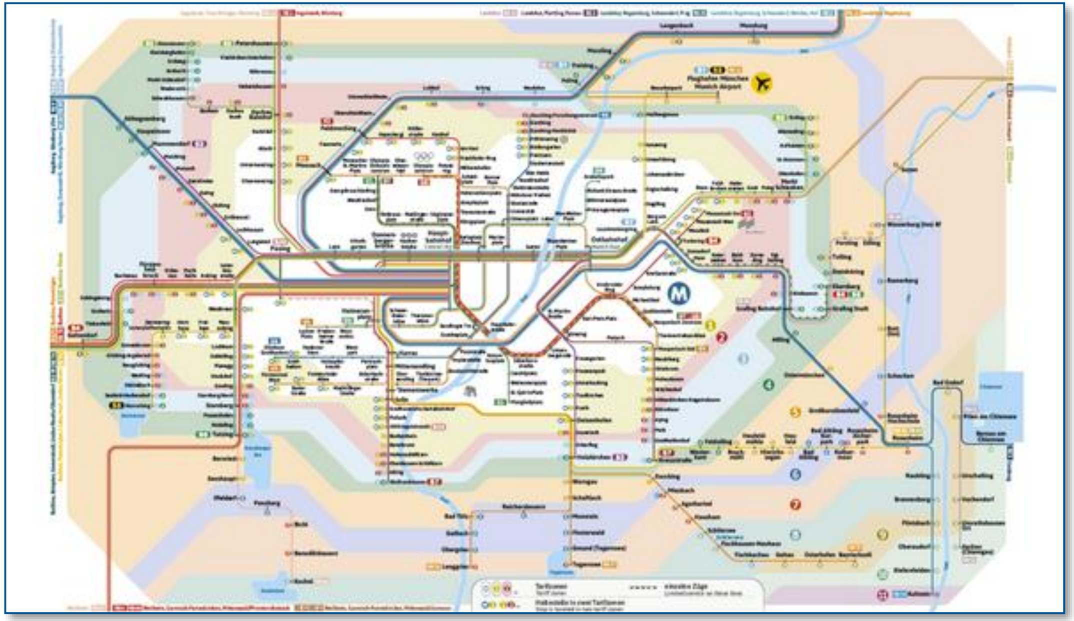
Filtering Trips Based On Random Utility Theory





Recreational Trips?

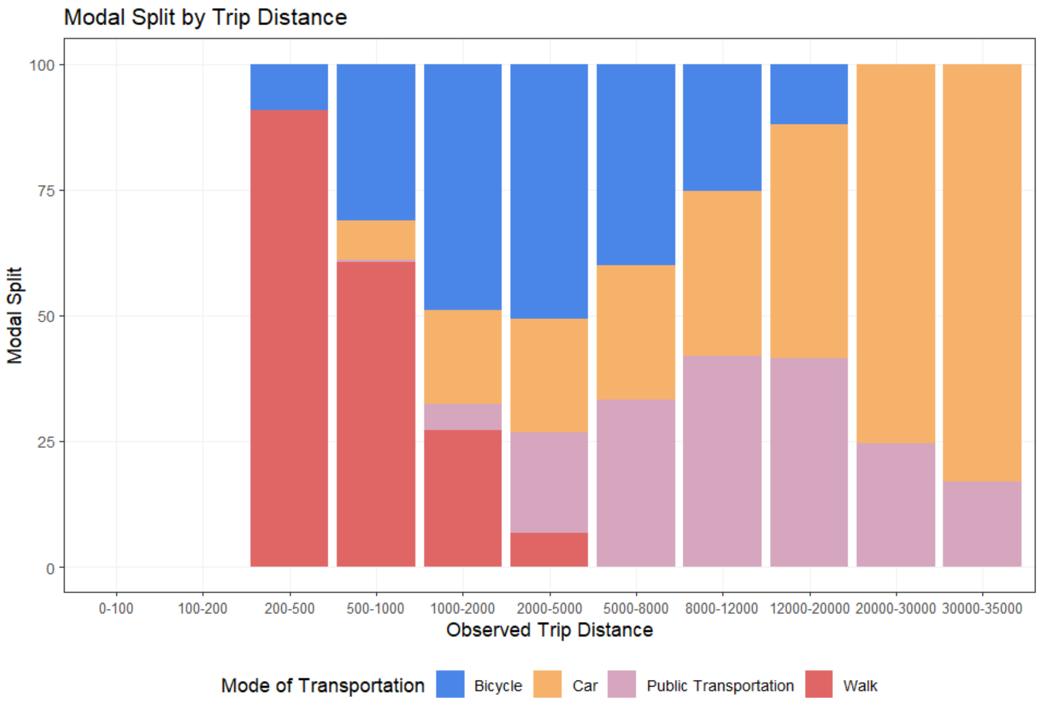
The 9-Euro-Ticket:
Integrating Systems and Reducing Costs



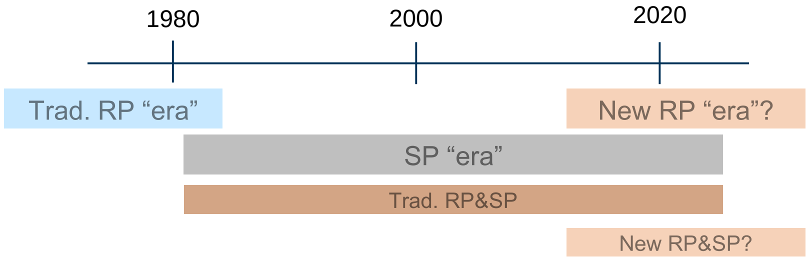
PREISE FÜR BEFAHRENE ZONEN IN € / Fares for your zones in €								
M	1, 2, 3, 4, 5, 6	1-2, 2-3, 3-4, 4-5, 5-6	M-1, 1-3, 2-4, 3-5, 4-6	M-2, 1-4, 2-5, 3-6	M-3, 1-5, 2-6	M-4, 1-6	M-5	M-6
20,20	20,20	20,20	32,60	40,40	50,50	59,40	68,60	77,80
63,20	63,20	63,20	101,80	126,20	157,60	185,50	214,20	242,70

9.00 € per month

Results of the Comprehensive Filtering



SP vs RP data: a new (old) topic



Historical context

- Technological advances have disrupted the game in the last 10-20 years
  - Smartphones + Internet connectivity
  - Accurate GPS
  - Decreasing cost for processing and storage of big data
  - External data sources to enrich the models (weather data, land-use, …)
  - …
- Collection of high accuracy panel data for long time periods at relatively low cost -> **“New” RP data**