The impact of autonomous vehicles on accessibilities in a metropolitan region

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Focus of this study

- Autonomous cars
  - An upcoming means of travel

- Accessibilities
  - An upcoming means of transport policy analysis

AUTONOMOUS VEHICLES

Autonomous vehicles

- Arguably great impact on patterns of movement
- Might to change the way people accommodate their wish to participate in activities
- Potential to increase mobility options and flexibility
- Stronger reliance of transport systems on autonomous vehicles might lead to problems in terms of equity

Some Facts and Expectations

- Developments in AV technology will sooner or later lead to new taxi-like services
- Service provision is expected to be very cheap
- Private (self-driven) cars
  - Usership may decline if AV services are as reliable as car trips
- Public transport
  - Ridership may decline if AV services are as cheap as PT

ACCESSIBILITIES

What is the goal of transport and land use planning?

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- *Improve mobility?*
  - Increase in the territory that can be reached for a given investment of time and money

- *Improve accessibility?*
  - Increase in the (value of) destinations that can be reached for a given investment of time and money

(Definitions by Jonathan Levine, NECTAR Cluster 6 Workshop)

Example

Example

Example

Example

Example

What is the goal of transport and land use planning?

- More Destinations
  - -> Better

- A destination more easy to reach
  - -> Better

An econometric accessibility measure

- Utility at location i gained from opportunities at j:
- $U_{ij} = V_{perf} + V_{ij} + \varepsilon_{ij}$
  - V_{perf} = Utility of activity no matter where
  - V_{ij} = Utility of journey from i to j (usually negative)
  - ε_{ij} = Variation / person- or opportunity-specific corrections to V_{perf} and V_{ij}
- Assumption: Distribution of ε_{ii} is IID-Gumbel

$$P_i(j) = \frac{e^{\mu*(V_{perf}+V_{ij})}}{\sum_j e^{\mu*(V_{perf}+V_{ij})}}$$

- Expected Maximum Utility (EMU)

$$E(U) = \frac{1}{\mu} * \ln \sum_j e^{\mu*(V_{perf}+V_{ij})}$$

An econometric accessibility measure

- Expected Maximum Utility (EMU)

$$E(U) = \frac{1}{\mu} * \ln \sum_j e^{\mu*(V_{perf}+V_{ij})}$$

$$E(U) = V_{perf} + \frac{1}{\mu} * \ln \sum_j e^{\mu*V_{ij}}$$

$$E(U) = V_{perf} + A_i \quad \text{with} \quad A_i = \frac{1}{\mu} * \ln \sum_j e^{\mu*V_{ij}}$$

- If $\mu=1$ and $V_{ij} = -C_{ij}$ C_{ij} = Generalized costs to get from i to j

$$A_i = \ln \sum_j e^{-C_{ij}}$$

Accessibility computation example

$$A_i = \ln \sum_j a_j \cdot e^{-c_{ij}}$$

1

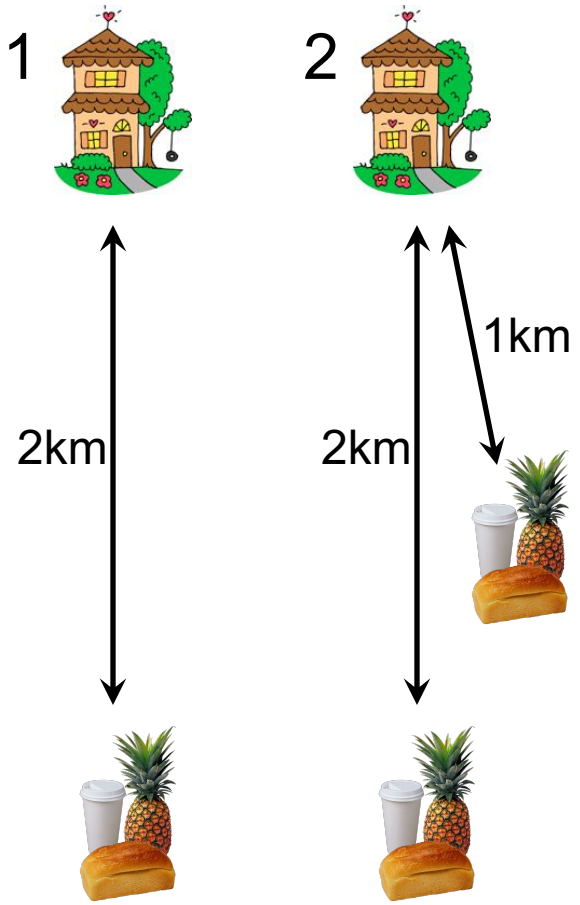
2km

$$A_i = \ln(e^{-2})$$

$$= -2$$

Accessibility computation example

$$A_i = \ln \sum_j a_j \cdot e^{-c_{ij}}$$



$$A_i = \ln(e^{-2})$$
$$= -2$$

$$A_i = \ln(e^{-2} + e^{-1})$$
$$= \ln(0.135 + 0.368)$$
$$= -0.687$$

Accessibility computation example

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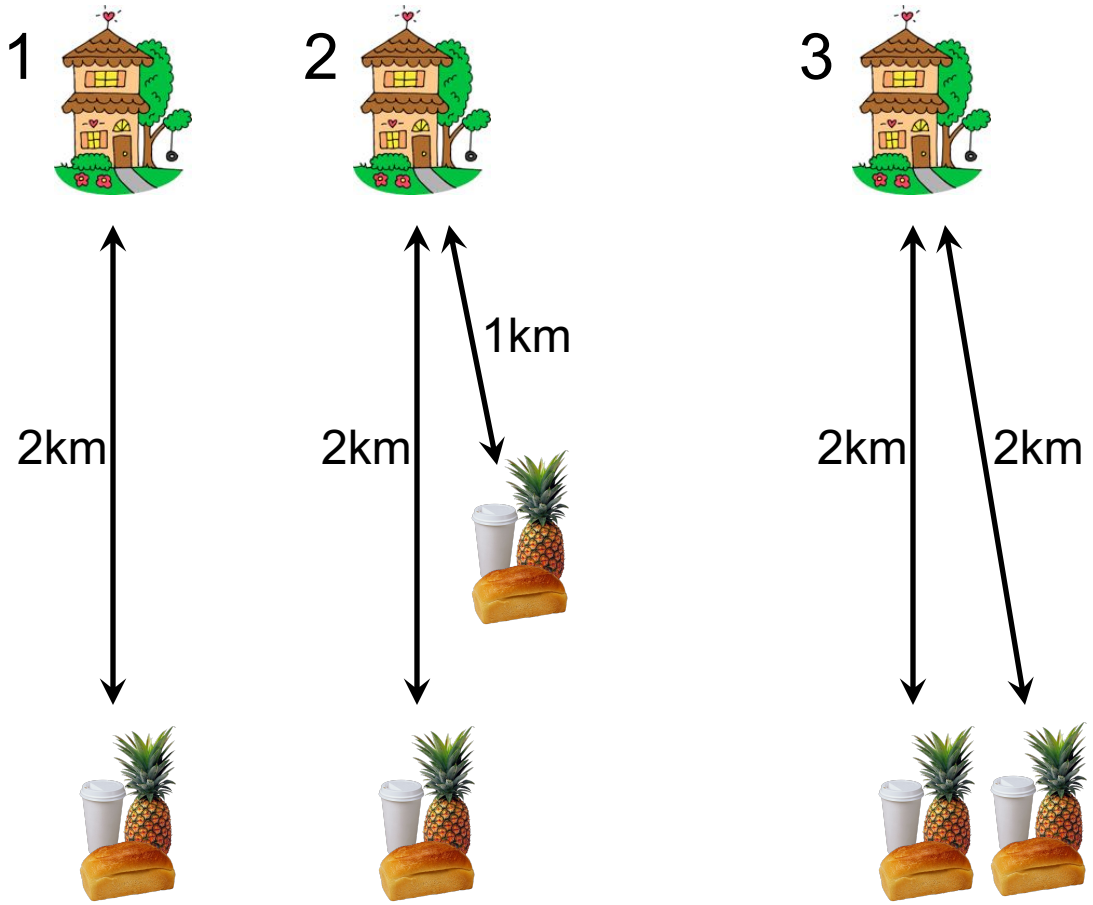

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Accessibility computation example

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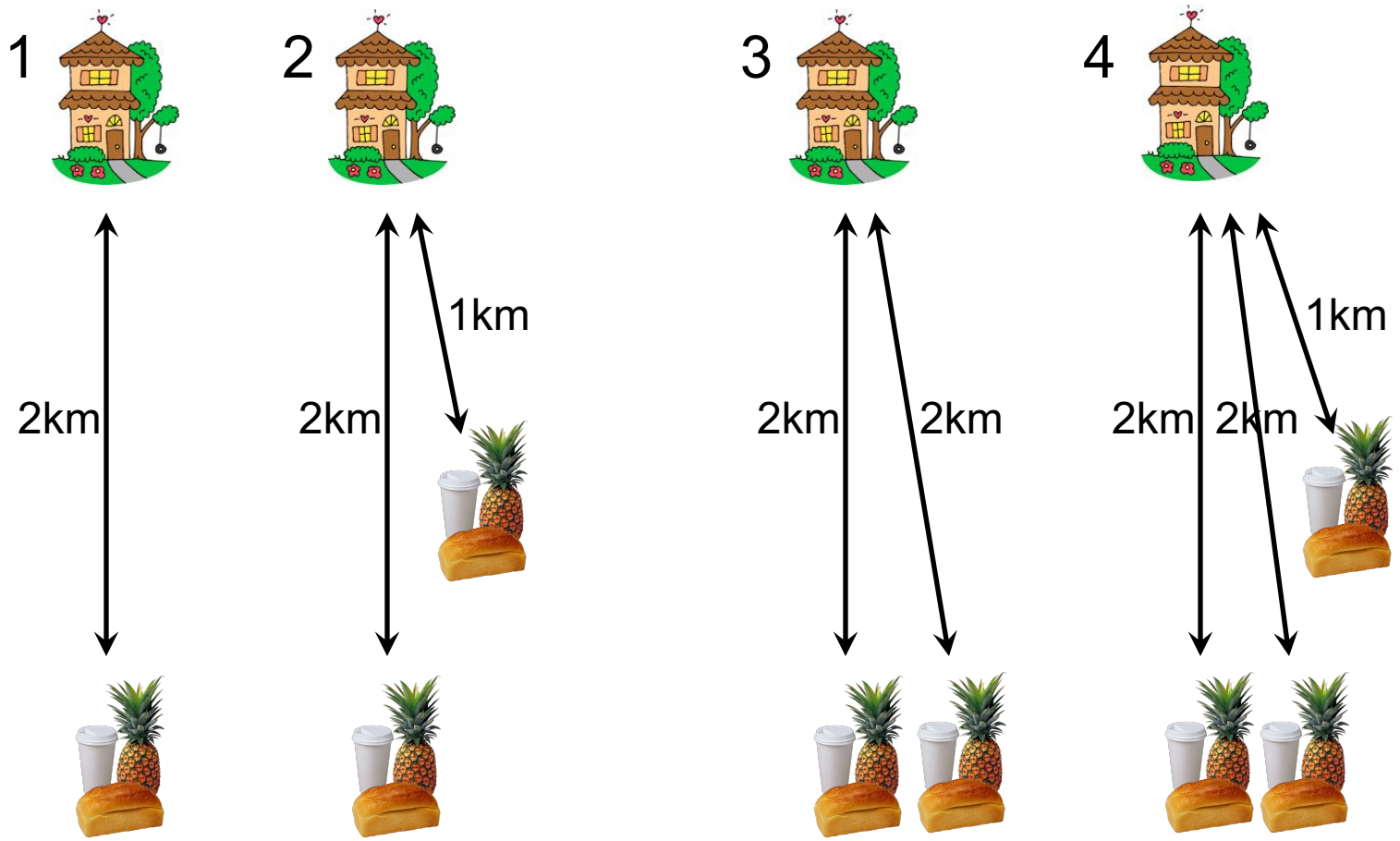

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Accessibility computation example

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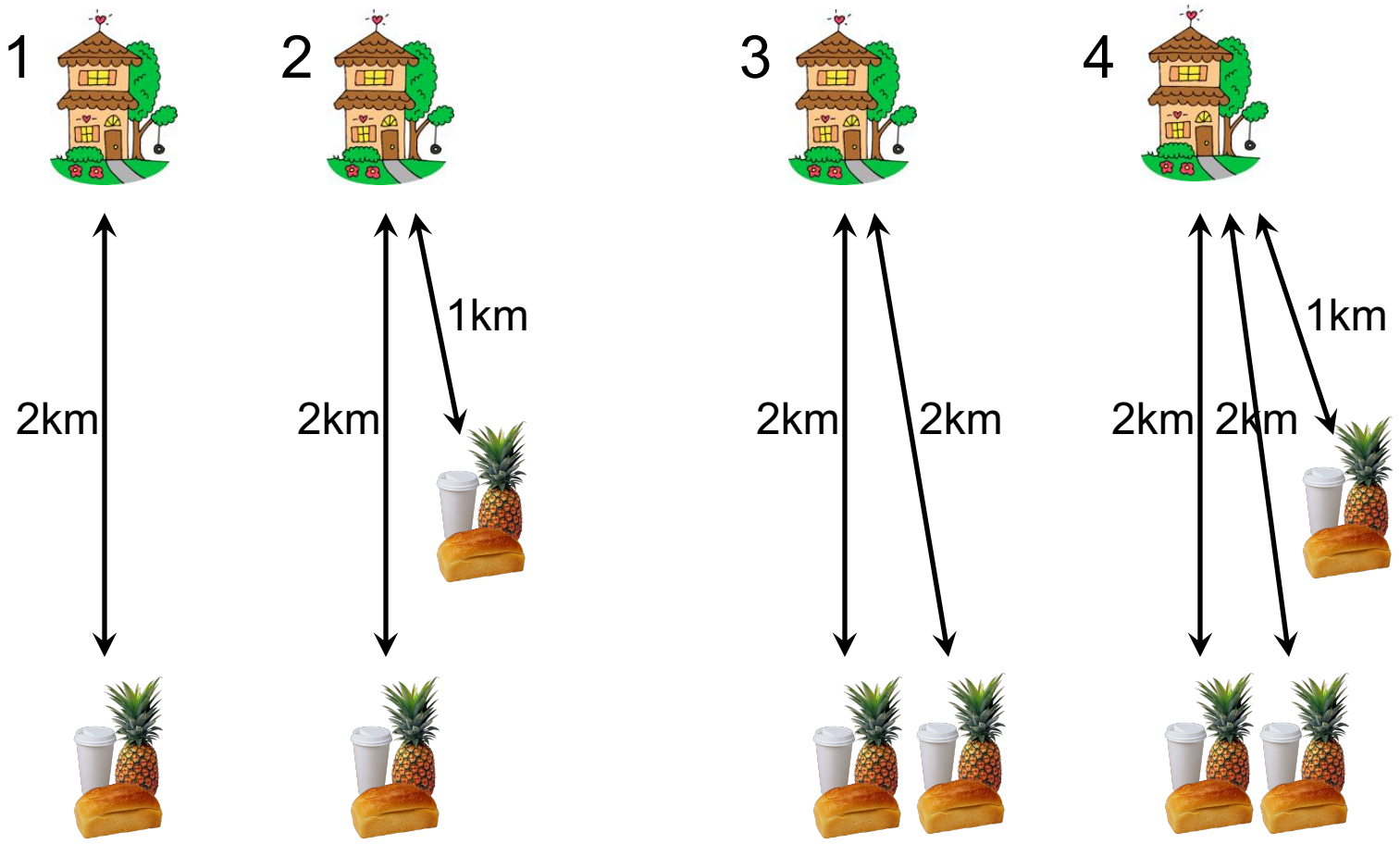

$A_i = \ln(e^{-2})$

$= -2$

+1.313

$A_i = \ln(e^{-2} + e^{-1})$

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Accessibility computation example

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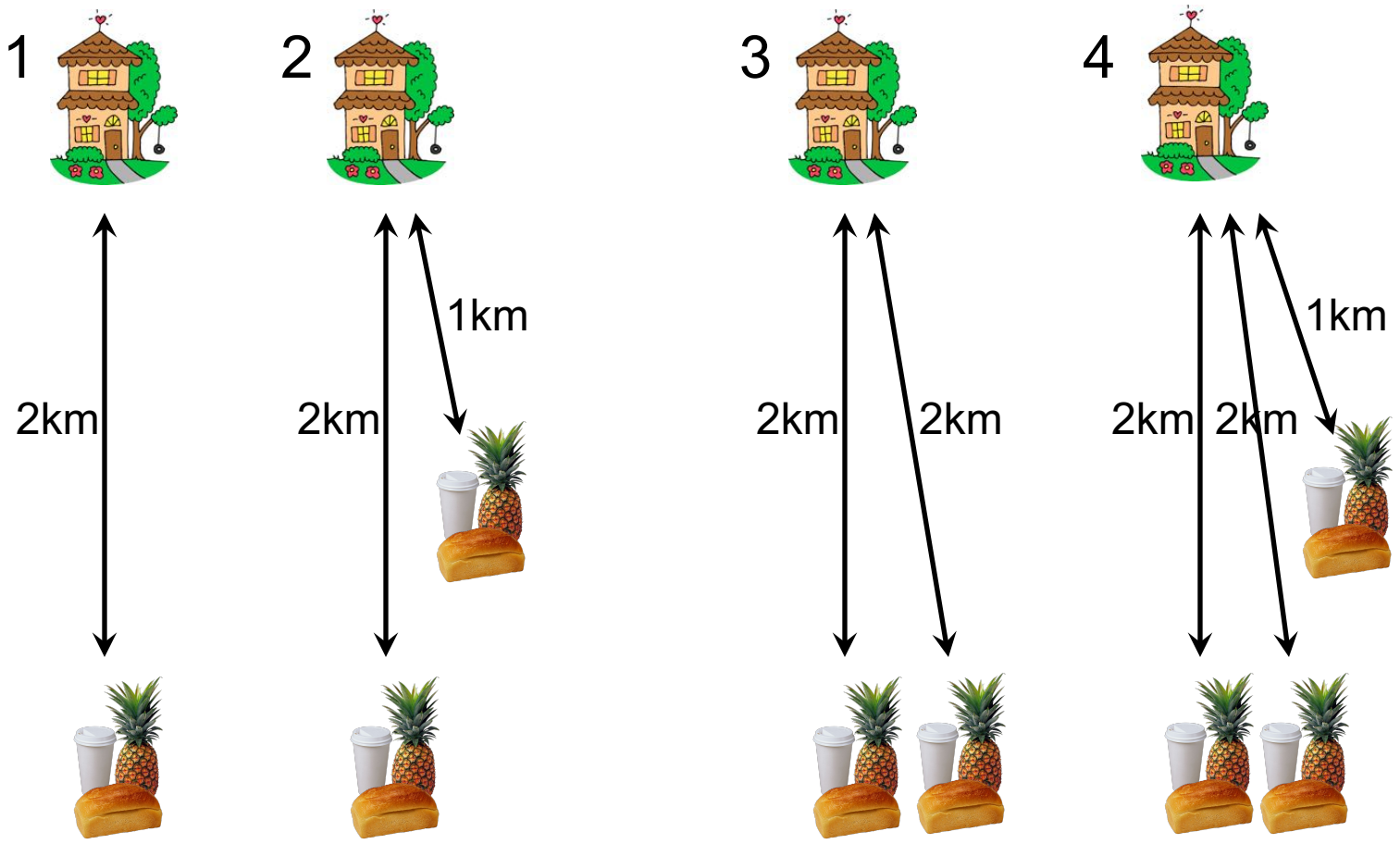

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How does is work?

- Calculate accessibility A_i of a given origin location i to opportunity locations j
  - Origin location i and opportunity locations j are assigned to the road network
  - For every i, compute a least cost path tree
    - Find best route with least cost C_{ij} between i and j
    - Based on Dijkstra's algorithm
    - Includes cost of network access/egress
- For different modes: Free-speed car, time-dependent congested car, bicycle, public transport, etc.
- For different opportunity types: Shopping facilities, leisure facilities, workplace, etc.

Accessibilities integration in Dynamic Transport Simulation

Time dependencies

- Dynamic transport system characteristics
  - Individual transport: Congestion
  - Public transport: Schedule (+ congestion)
- Opening times of activity facilities

Data models and input data preparation procedures of MATSim

- Network generation based on OSM
- Facility generation based on OSM
- Public transport schedule generation based on GTFS

BERLIN AV/AT ACCESSIBILITY CASE STUDY

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Case Study for Berlin

- Changes in terms of activity participation opportunities in a possible future transport system, which is more strongly reliant on autonomous cars

- Analysis Instrument: Accessibilities

- Accessibilities computed for
  - Public transport (schedule-based)
  - Autonomous cars that operate as mobility-as-a-service
  - Private car

- Accessibilities to education facilities at 8:00:00

Modeling assumption

- Waiting time has same (dis)utility as in-vehicle travel time (relevant for ATs and PT)
- Access/egress time and time to change vehicles as well (relevant for PT)
- AVs travel with same speeds (and same congestion) as ‘regular’ cars

Dynamics in the system

- Travel time depends on congestion (private cars and ATs)
- Waiting time until pick-up depends on demand and congestion (ATs)
- Dependency on PT schedule (PT)

AT operating rules

- Request
  - Dispatch the nearest idle taxi **OR** queue request
- Drop-off
  - Wait **OR** serve the **nearest** waiting request
- Destinations of AT trips unknown when trip requested
  - Waiting time origin-specific

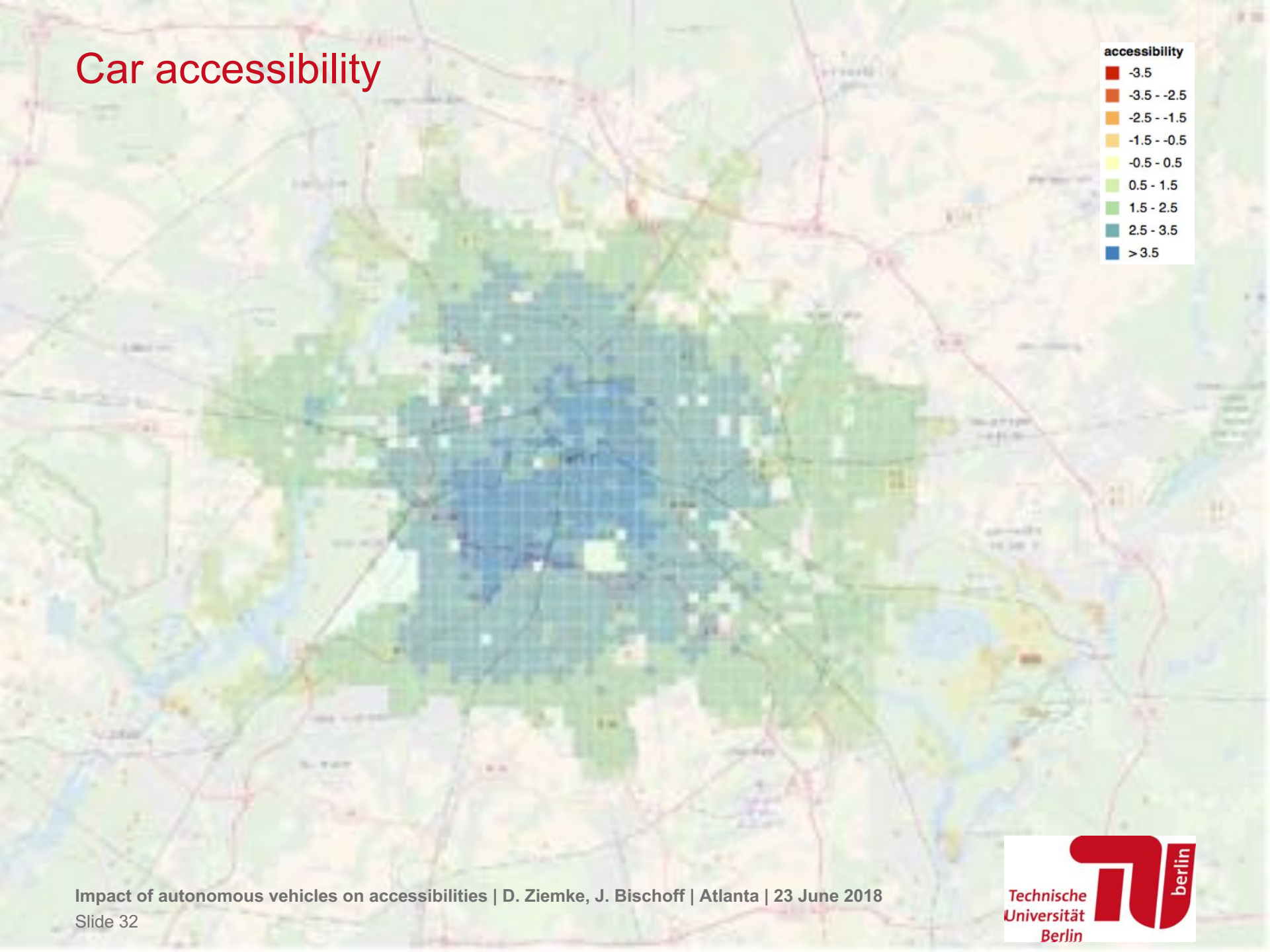
Modeling AT pick-up times

- MATSim Open Berlin Scenario
- 10% of agents who travelled by PT before want to make their trip by AT
- Measure pick-up/waiting time and assign to measure point of accessibility computation grid
- Do this 10x (with different randomly chosen 10% of agents) and average

➢ Location-based, time-dependent AT pick-up times

RESULTS

Car accessibility



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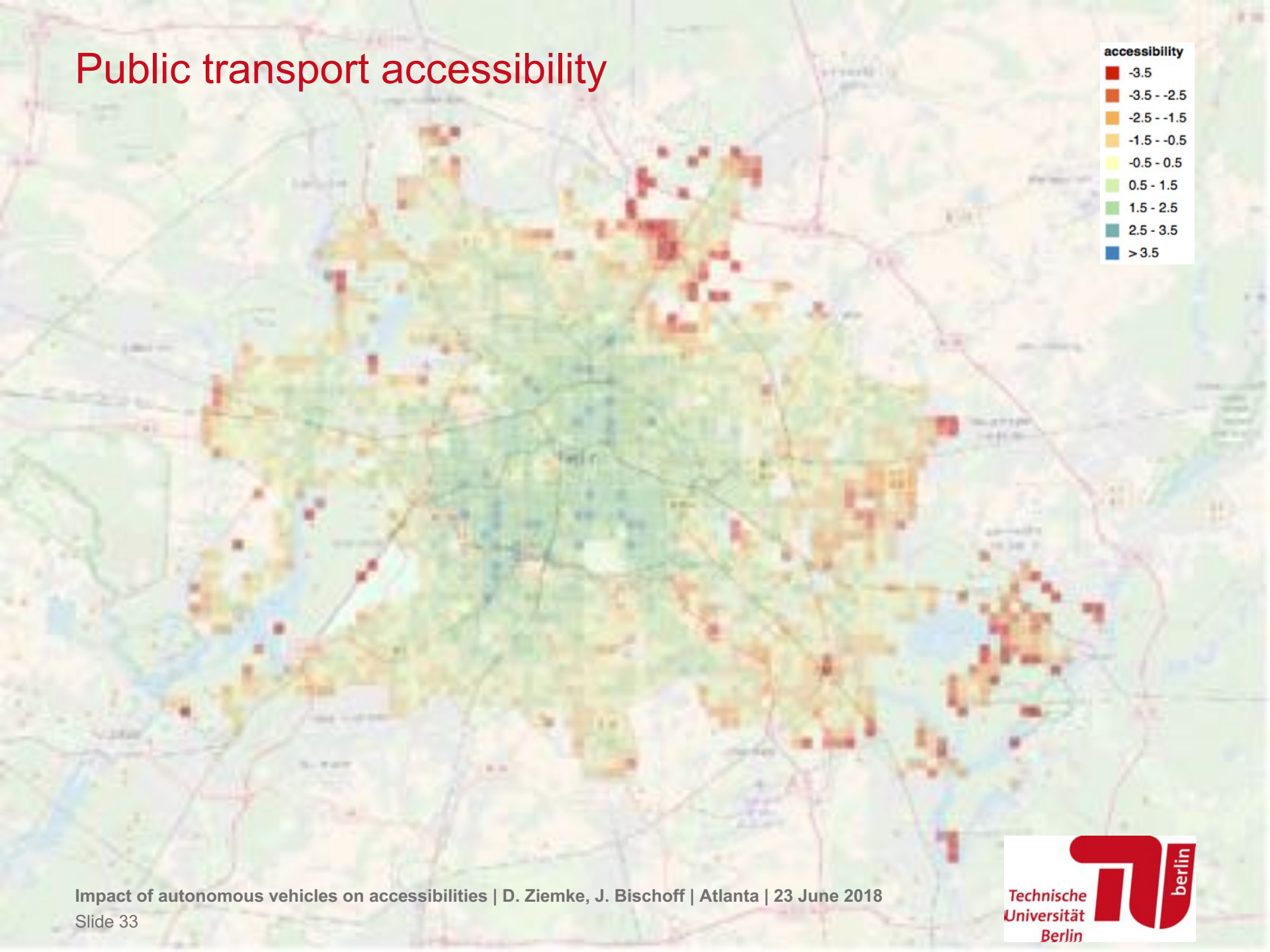
Public transport accessibility



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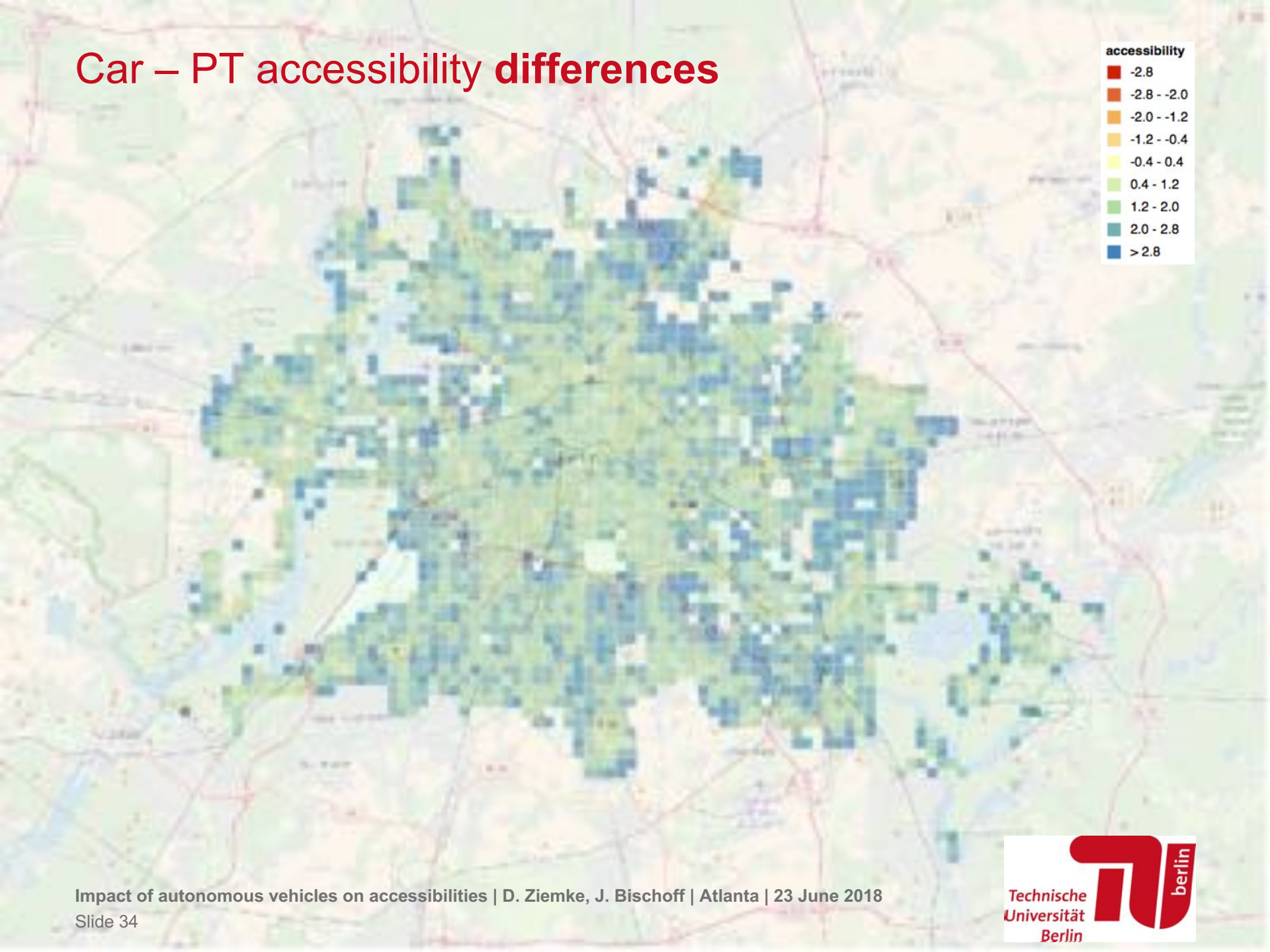
Car – PT accessibility **differences**



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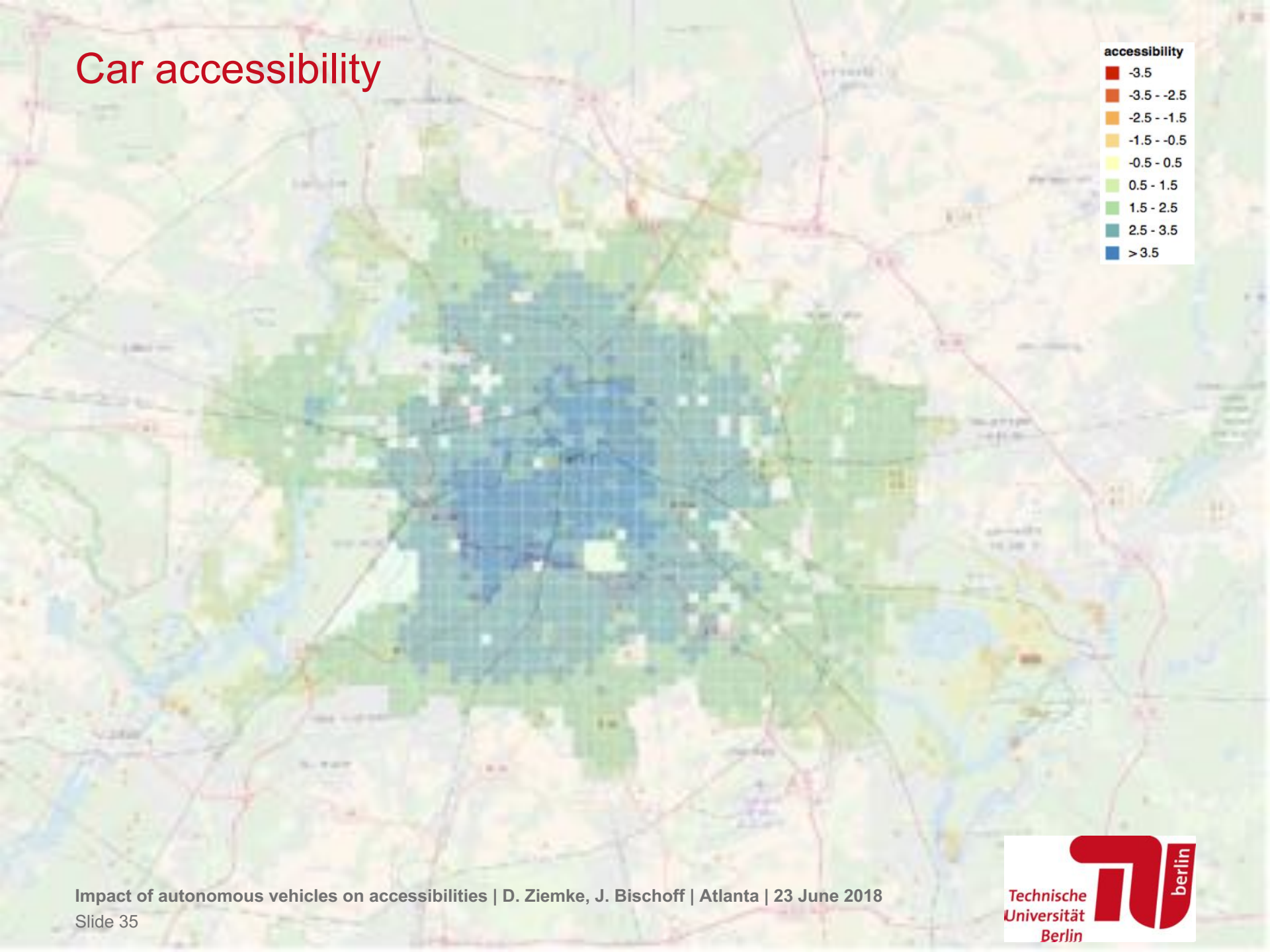
Car accessibility



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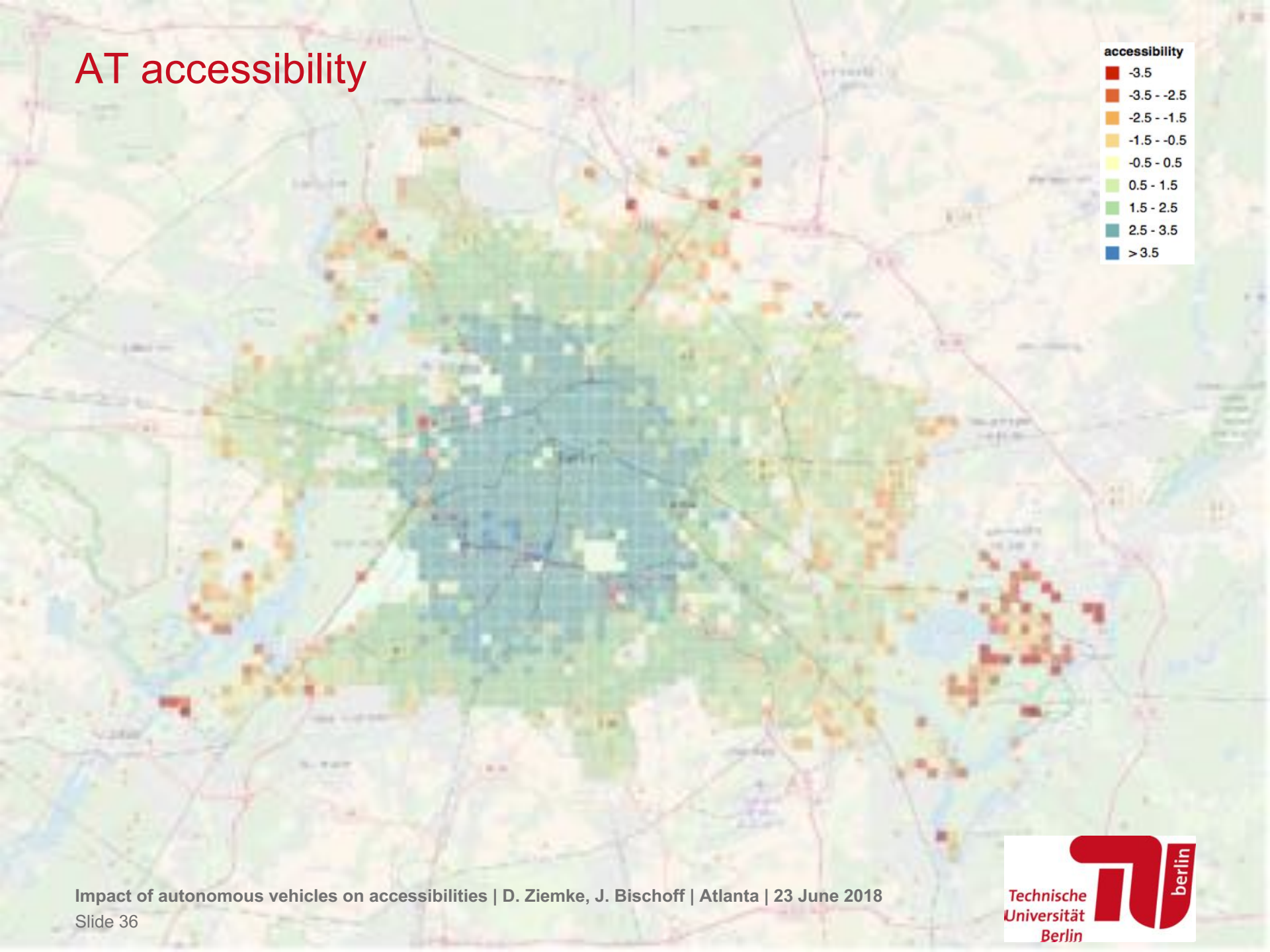
AT accessibility



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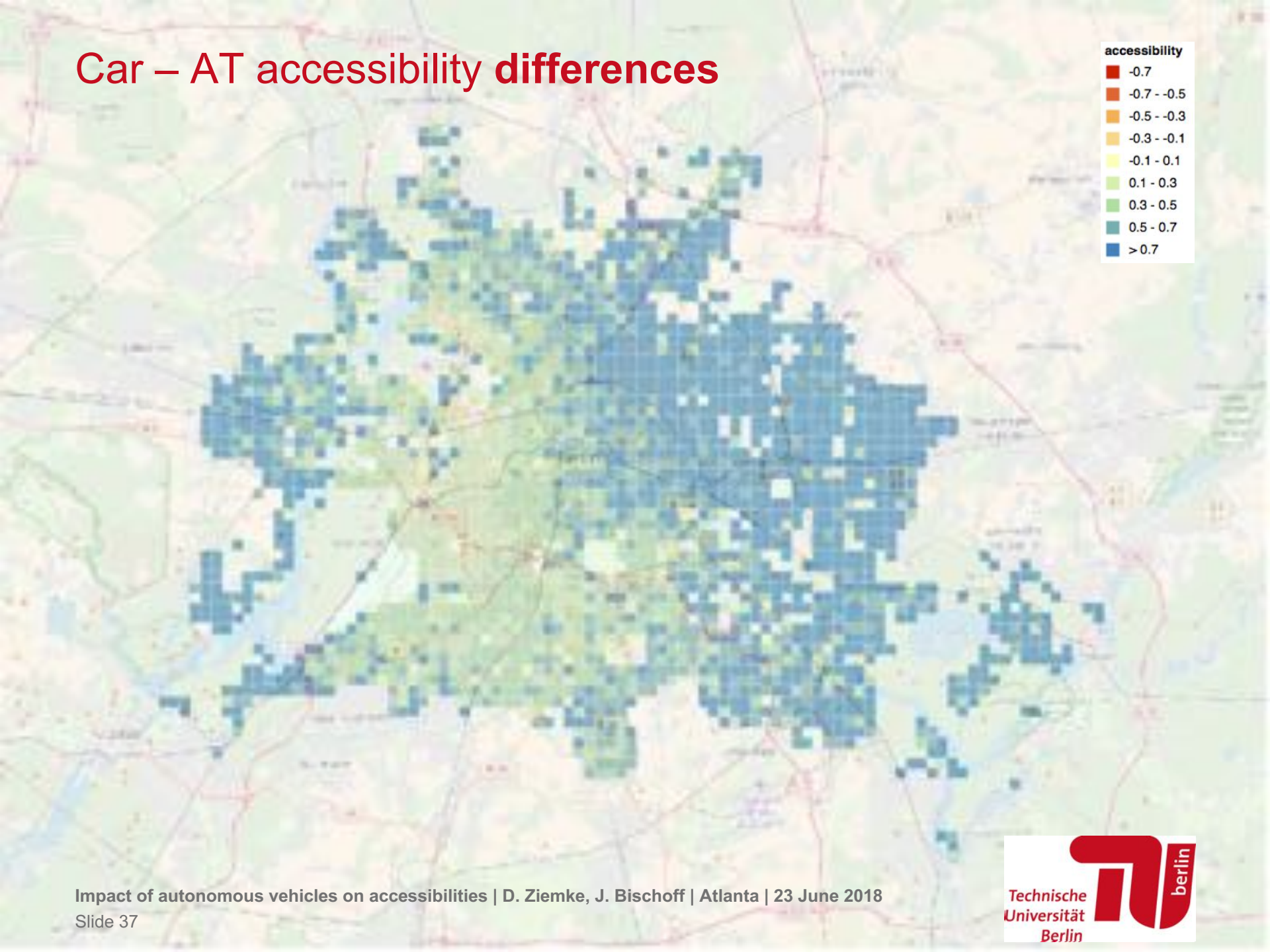
Car – AT accessibility **differences**



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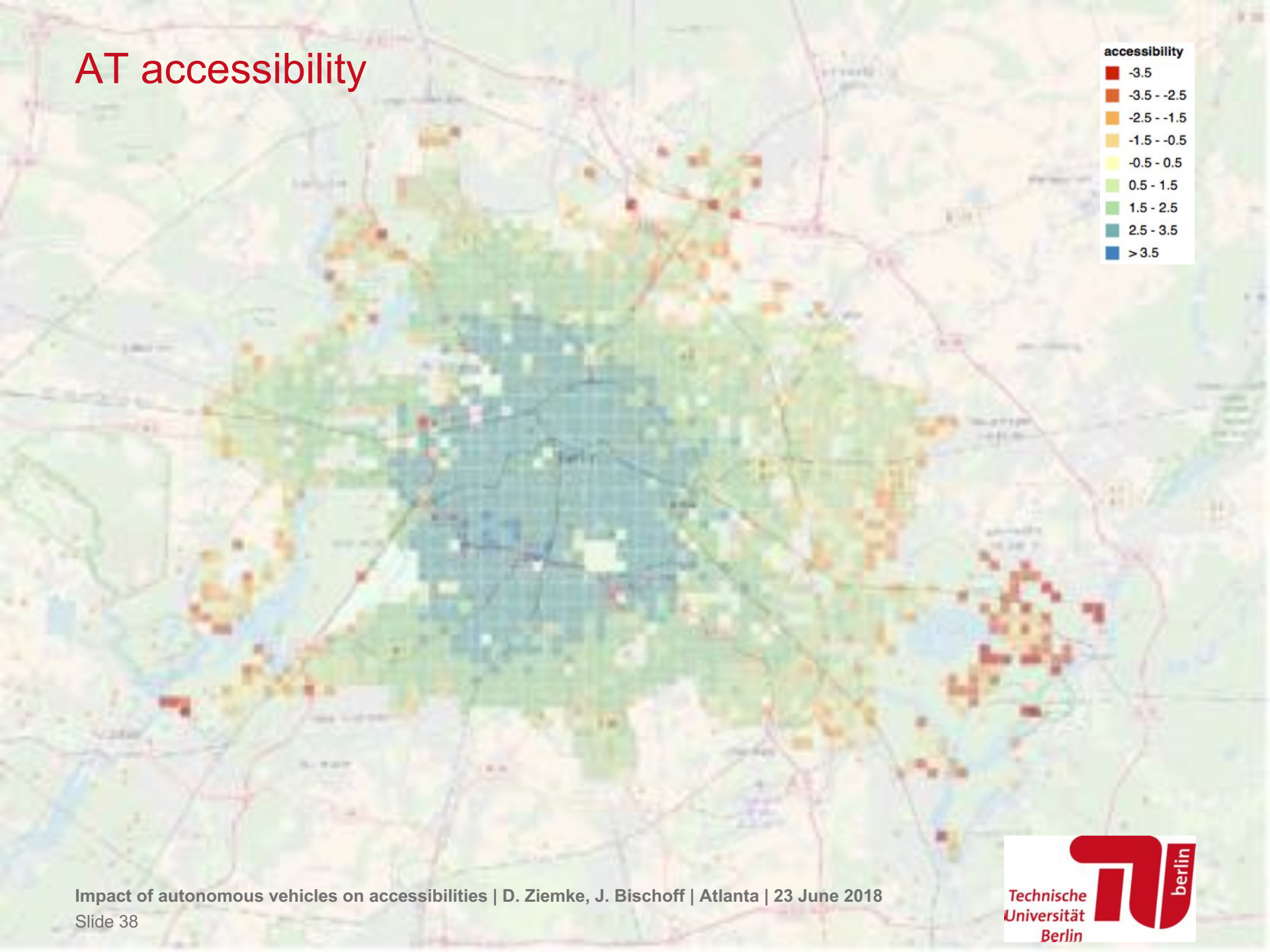
AT accessibility



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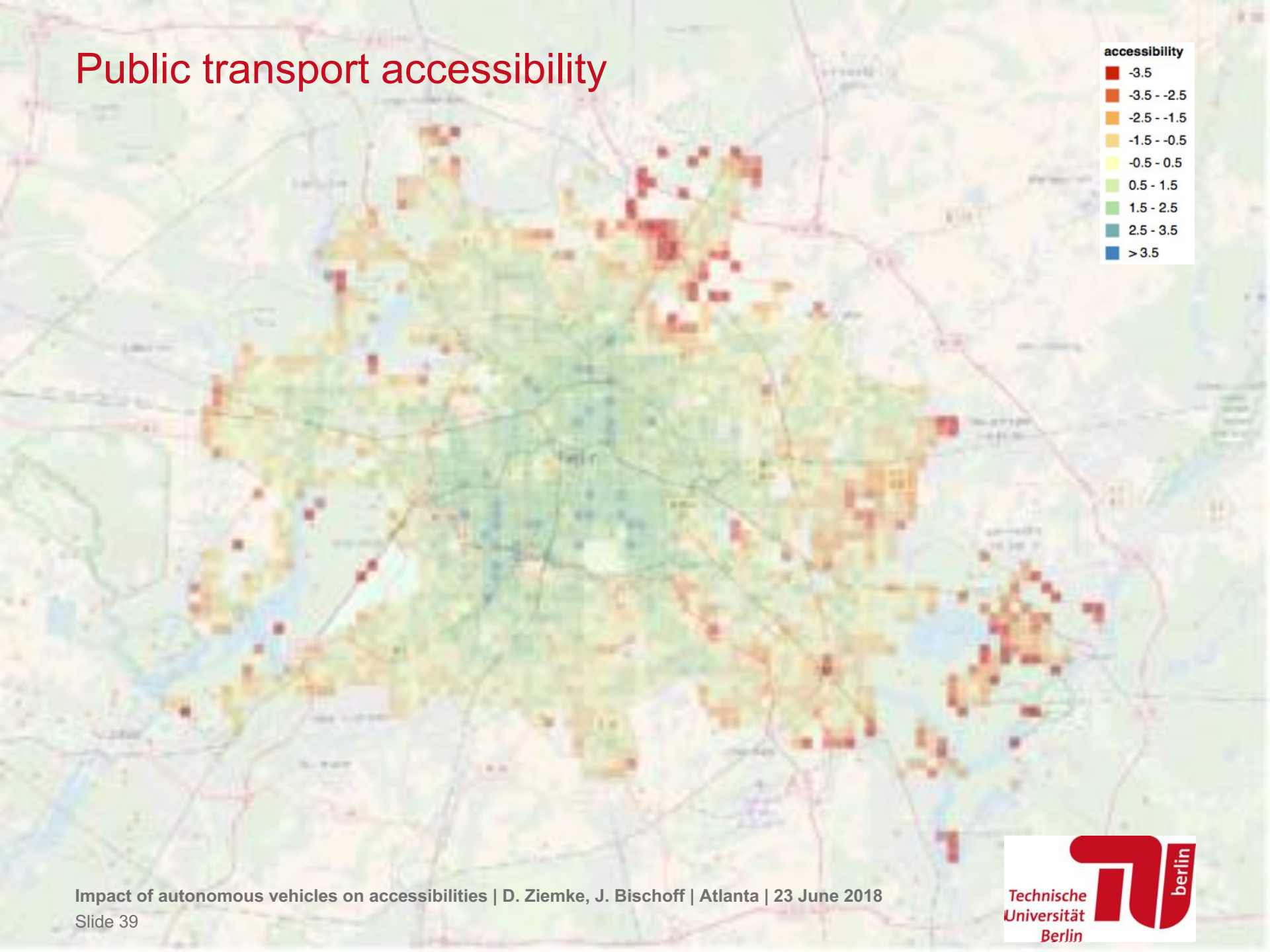
Public transport accessibility



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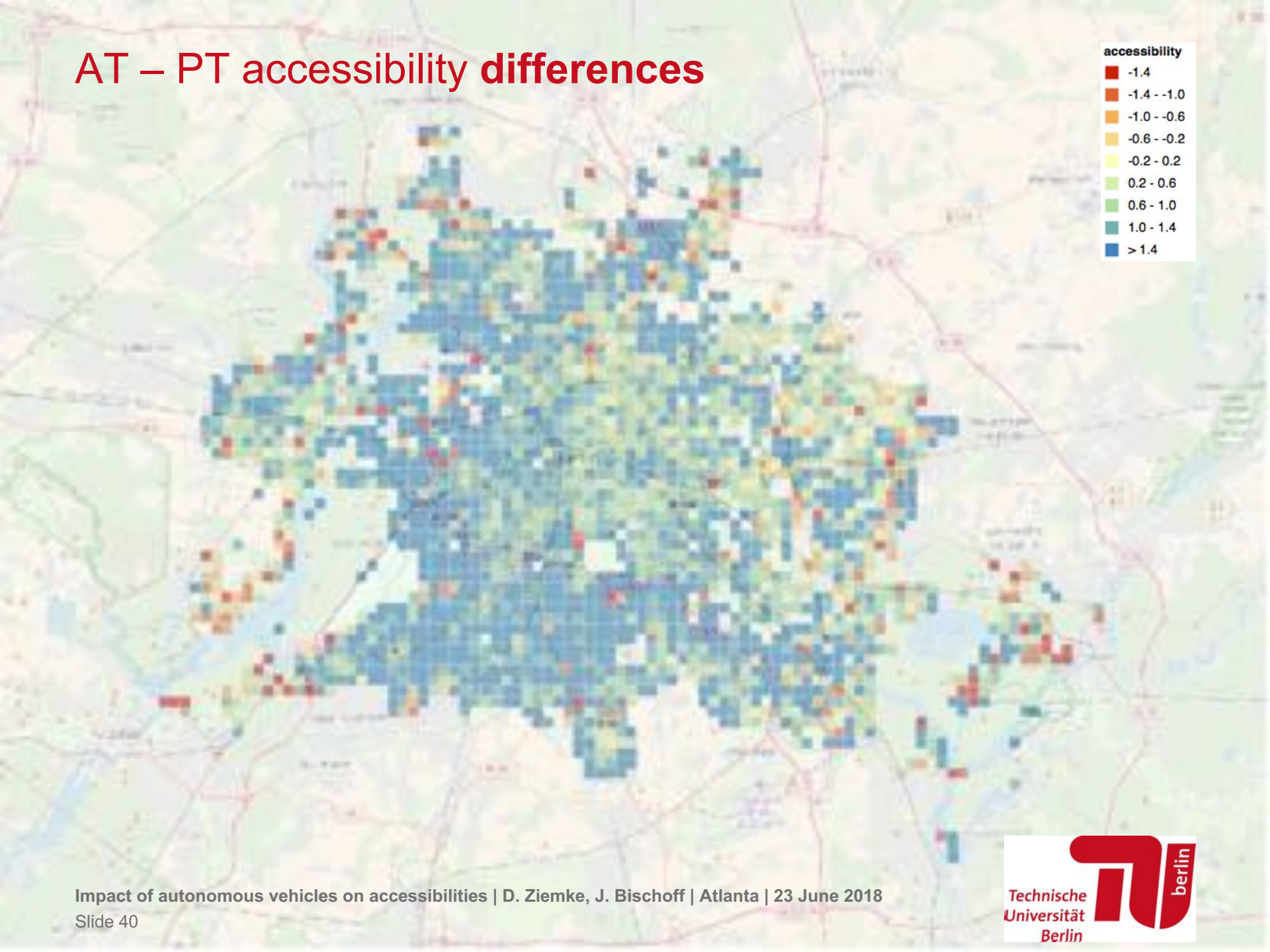
AT – PT accessibility **differences**



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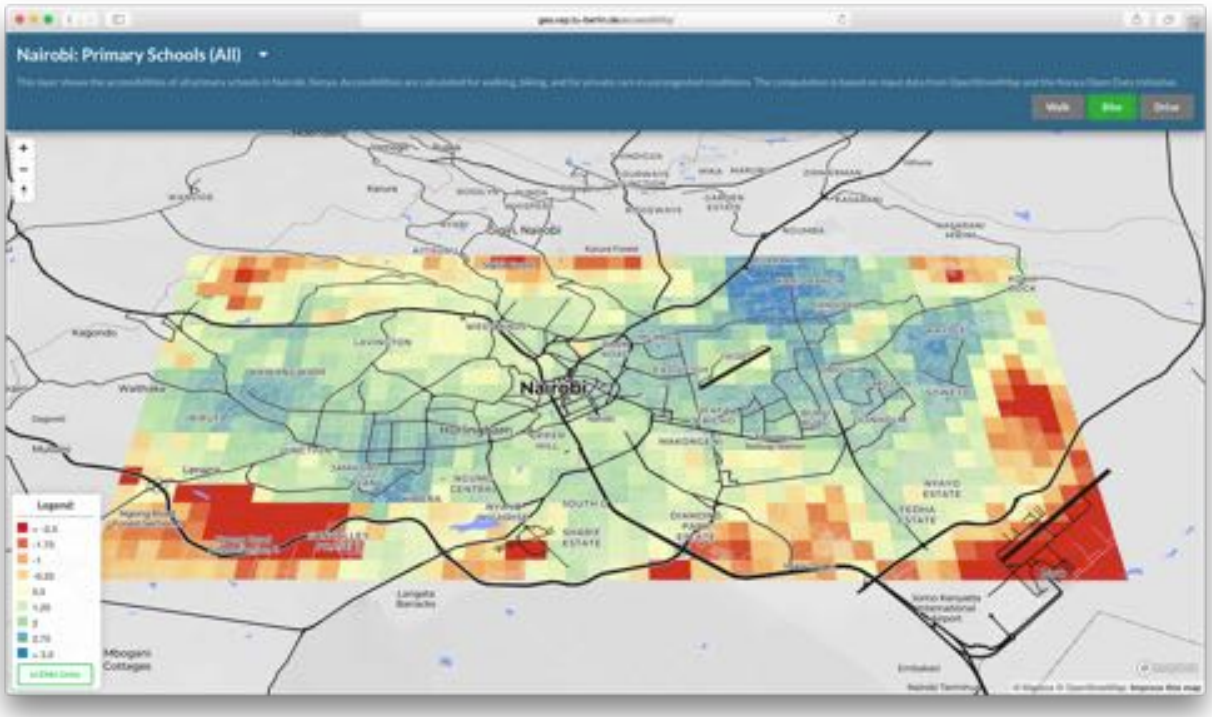
Some first findings

- Car-to-PT accessibility advantage small in city center
- AT accessibility between car and PT accessibility
- Car-to-PT accessibility advantage greater in the East
- AT-to-PT accessibility advantage greater in the West



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Thank you!

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