Modal disparities in spatiotemporal accessibility to non-work activities on the commute home from work in Warsaw, Poland

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Motivation

- Urban spatial structure has environmental, economic, social impacts
  - **Low-density, dispersed** versus **high-density, compact**
    - Consequences/outcomes
      - Societal: energy use, accidents, productivity,
      - Individual: **accessibility to employment and non-work activities**
- Public transport friendly built environments
  - Less energy use
  - Cheaper and better accessibility to jobs, goods, services
- Disparity between car and public transport accessibility
  - Degree of public transport supportive urban structure

Modal accessibility disparity

- Focus on accessibility to jobs only
  - Blumenberg & Hess, 2003; Kwok and Yeh, 2004; Kawabata, 2009; Kawabata & Shen, 2006, 2007; Yang, et al., 2017
- Accessibility to goods and services an integral part of functioning in modern society
  - Necessary items like food, clothing
  - Discretionary items like restaurants, jewelry, sporting goods
- Non-work travel at least 75% of all travel (Bartosiewicz & Pielesiak, 2019; Pisarski, 2013)
- Research shows inequities in non-work accessibility (Scott & Horner, 2008; Grengs, 2015; Horner et al., 2015)
- It is unknown how non-work accessibility varies by mode
  - Unknown where to target transport policy and/or land use development interventions to improve modal non-work accessibility gaps.
- Modal non-work accessibility disparity analysis complementary to modal job accessibility disparity

Modal accessibility disparity

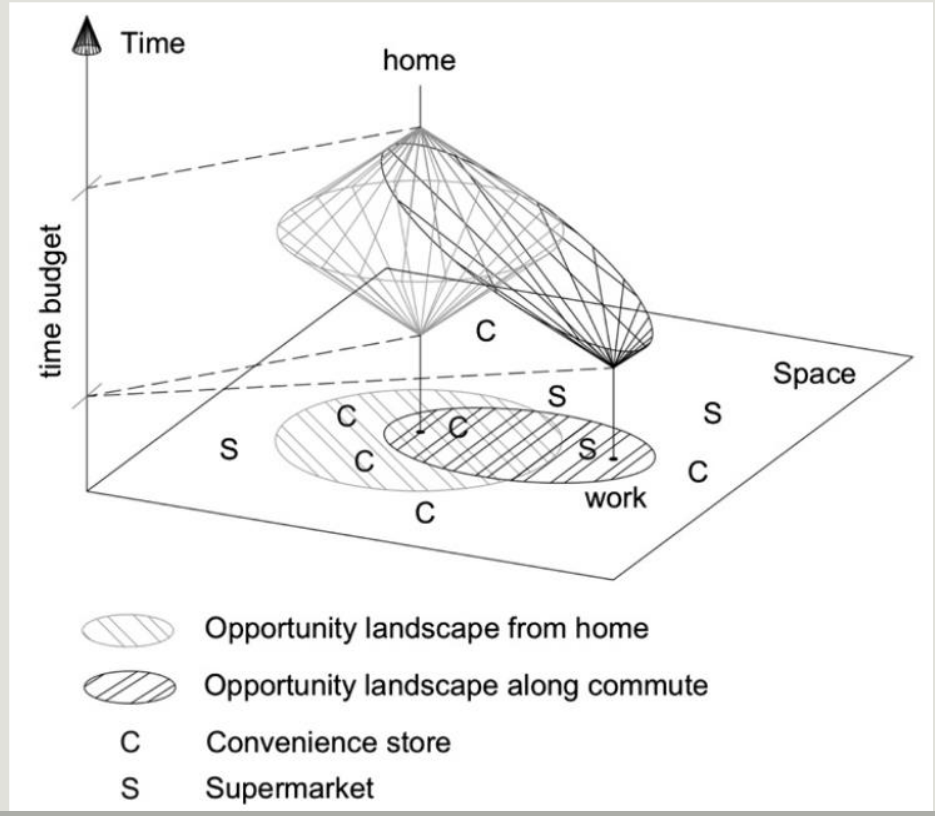
- Three other contributions to the modal disparity literature
  - Place-based cumulative opportunity metric with **space-time constraints**
    - Time budget is **not** always unlimited
  - Measure accessibility in minutes available
    - Discounting travel time to/from activity, and activity duration
  - Measure accessibility for different trip types
    - Commute-based
    - Home-based

Research questions

1) What is the extent of the regional modal disparity in the minutes available for grocery shopping and how does it vary by:
   a) trip type?
   b) time budget?
   c) activity duration?
2) How does the disparity vary by location within the city:
   a) for each trip type?
   b) by time budget?
   c) by activity duration?

Methods

- We adopt and adapt methods used by Widener et al. (2013; 2015) to calculate the **amount of minutes a person has to purchase** groceries in supermarkets.
- Based on the social interaction model by Farber et al. (2013)
- Potential path area is 2D representation of space-time prism
- Quantifies minutes available discounted travel time
- Two trip types
  - Home – supermarket – home
  - Work – supermarket - home



Methods

- Home-based accessibility
  - The number of minutes available on a home-based trip

$$ {}^{m}A_{iki} = max\left(0, B - \left({}^{m}t_{ik} + t_k + {}^{m}t_{ki}\right)\right) $$

    - *B* = total time budget in minutes
    - ${}^{m}t_{ik}$ = travel time in minutes using transport mode *m* from home location *i* to non-work location *k*
    - t_k = minimum time required to participate in activity at location *k*
    - ${}^{m}t_{ki}$ = travel time in minutes using transport mode *m* from non-work location *k* to home location *i*
  - Report it by home location *i*

$$ {}^{m}A_i^H = \frac{\sum_{k \in K_{ii}} {}^{m}A_{iki}}{n} $$

    - K_{ii} is the set of *n* supermarkets accessible within B minutes on the trip from and to home

Methods

- Commute-based accessibility
  - The number of minutes available on a home-based trip

$$ {}^{m}A_{jki} = max\left(0, B - \left({}^{m}t_{jk} + t_k + {}^{m}t_{ki}\right)\right) \forall i,j \in {}^{m}X_{ji} > 0 $$

    - B = total time budget in minutes
    - ${}^{m}t_{jk}$ = travel time in minutes on transport mode *m* from work location *j* to non-work location *k*
    - t_k = minimum time required to participate in activity at location *k*
    - ${}^{m}t_{ki}$ = travel time in minutes on transport mode *m* from non-work location *k* to home location *i*
    - ${}^{m}X_{ji}$ = number of workers travelling on transport mode *m* from work location *j* to home location
  - Report it by home location *i*

$$ {}^{m}A_i^C = \sum_j \frac{\sum_{k \in K_{ji}} A_{jki}}{n} $$

    - K_{ji} is the set of *n* supermarkets accessible within B minutes on the work-to-home trip

Methods

- Modal accessibility disparity
  - We use a standardized disparity measure based on Kwok & Yeh (2004)

	Home-based	**Commute-based**
Zonal	$X_i^H = \frac{{}^{PT}A_i^H - {}^{Car}A_i^H}{{}^{PT}A_i^H + {}^{Car}A_i^H}$	$X_i^C = \frac{{}^{PT}A_i^C - {}^{Car}A_i^C}{{}^{PT}A_i^C + {}^{Car}A_i^C}$
Regional	$X^H = \frac{\frac{\sum_i {}^{PT}A_i^H}{n} - \frac{\sum_i {}^{Car}A_i^H}{n}}{\frac{\sum_i {}^{PT}A_i^H}{n} + \frac{\sum_i {}^{Car}A_i^H}{n}}$	$X^C = \frac{\frac{\sum_i {}^{PT}A_i^C}{n} - \frac{\sum_i {}^{Car}A_i^C}{n}}{\frac{\sum_i {}^{PT}A_i^C}{n} + \frac{\sum_i {}^{Car}A_i^C}{n}}$

Study area

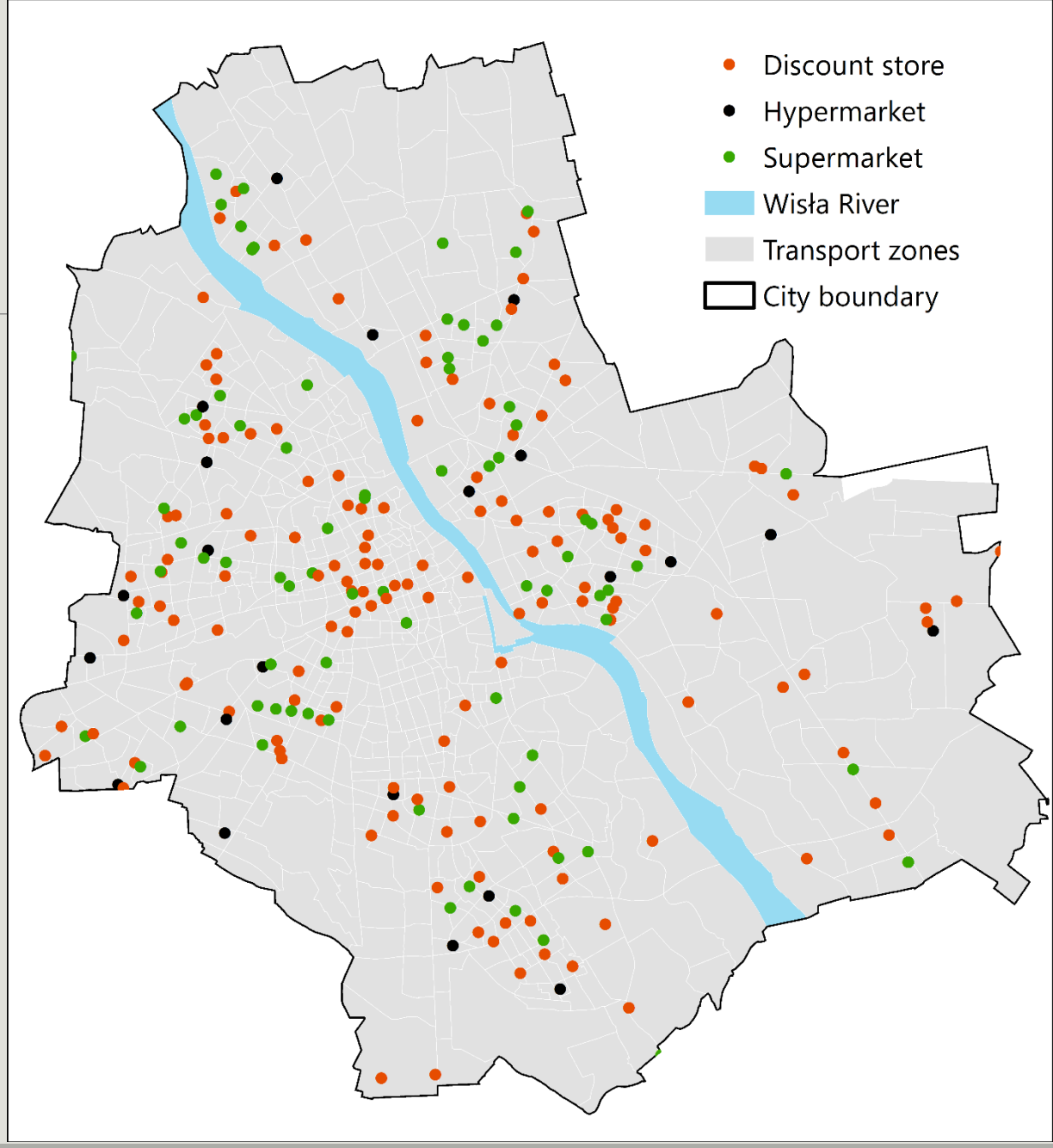
- Warsaw, Poland
  - City population (2016): 1,754,000
  - Metropolitan area (2016): 3,174,000
- Means of transportation, work-to-home
  - Car 36.3%
  - PT 53.1%
- Mean travel time, work-to-home
  - Car 32.3 minutes
  - PT 40.8 minutes

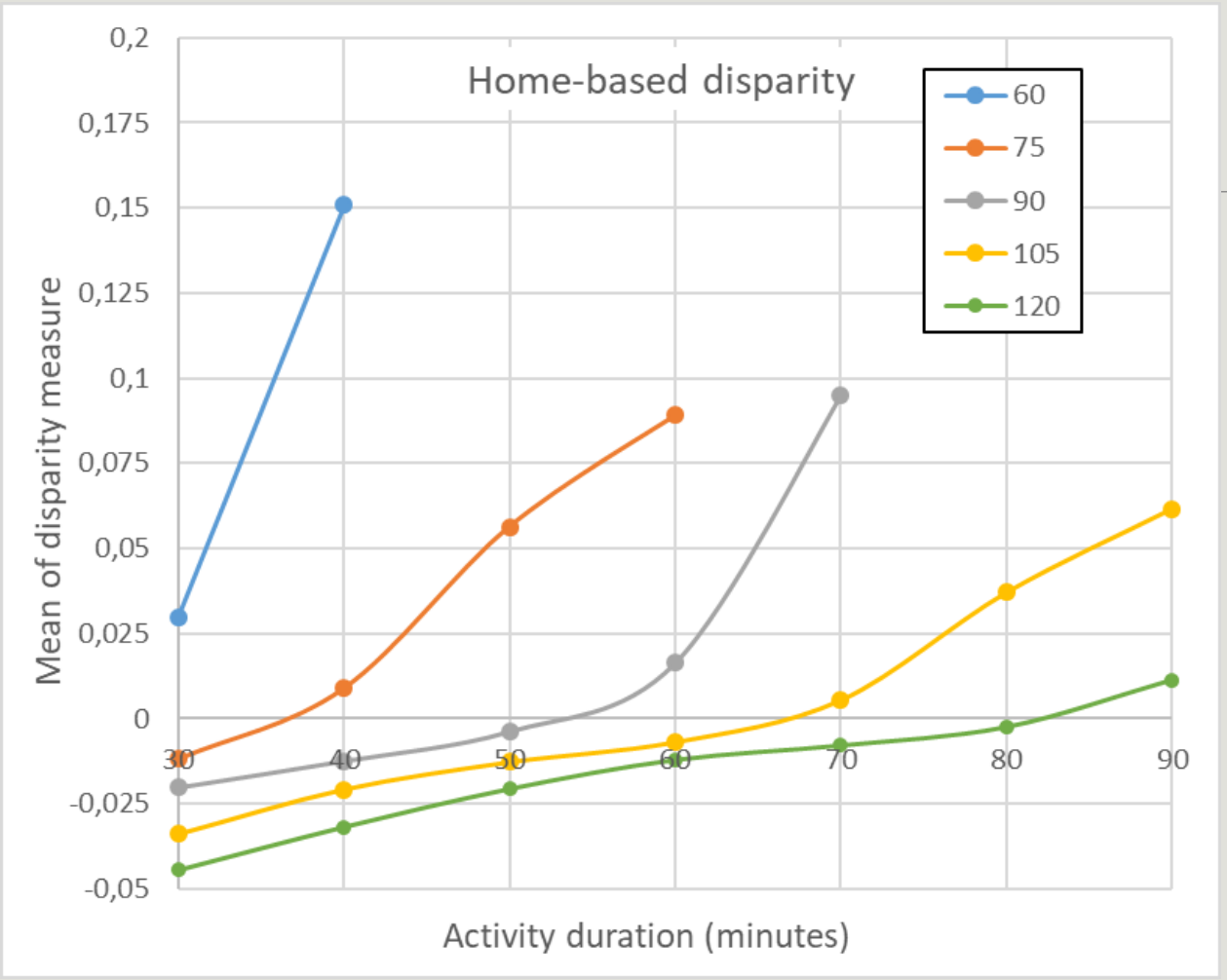
Data

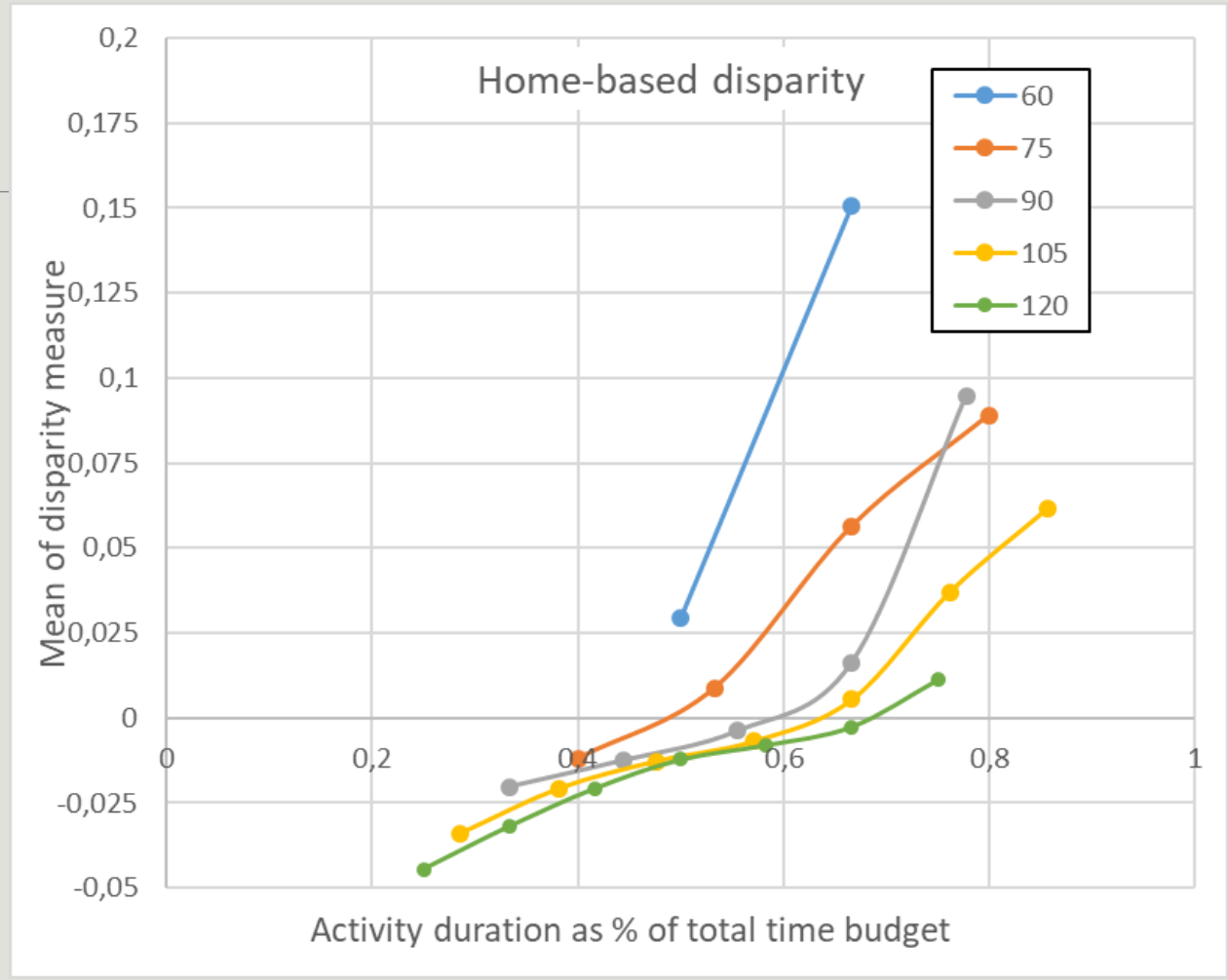
- Activity data
  - 2017 Business location database from Datawise.pl (local ESRI affiliate)
- Commuting data
  - 2015 Warsaw Traffic Survey (from the municipal government)
- Travel time data
  - From Warsaw Traffic Survey
  - Real congested travel time
  - Door-to-door:
    - transit: bus/tram/metro stop access/egress time, stop wait time, vehicle travel time, transfer time
    - cars: parked car access/egress time, drive time, parking space search time

Focus on grocery stores

- Supermarkets, hypermarkets, and discount stores
- Due to computational reasons
  - Use non-symmetric real congested travel time matrix for *iki* and *jki* trips
  - Matrix has size $n \times k \times n$
  - 798*346*798 = 220,334,184 records or ~10gb
- Scenarios
  - Combinations of time budget (B) and minimum activity duration (c_k), where $B > c\_k$
    - B = {60, 75, 90, 105, 120}
    - c_k = {30, 40, 50, 60, 70, 80, 90}




Home-based disparity
60
75
90
105
120
0,2
0,175
0,15
0,125
0,1
0,075
0,05
0,025
0
-0,025
-0,05
Mean of disparity measure
30
40
50
60
70
80
90
Activity duration (minutes)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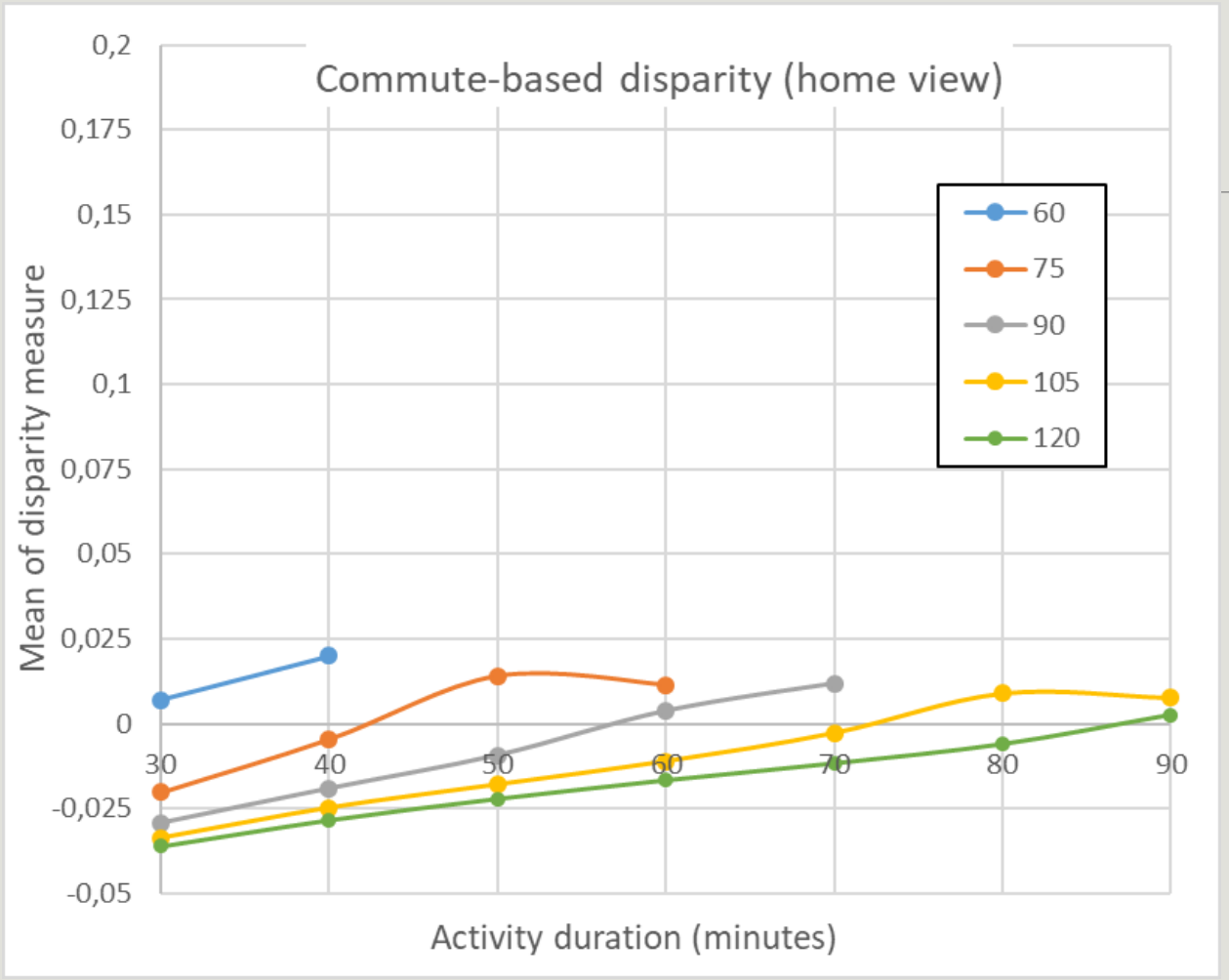
0,05
0,025
0
-0,025
-0,05
Mean of disparity measure
0
0,2
0,4
0,6
0,8
1
Activity duration as % of total time budget


Commute-based disparity (home view)
Mean of disparity measure
0,2
0,175
0,15
0,125
0,1
0,075
0,05
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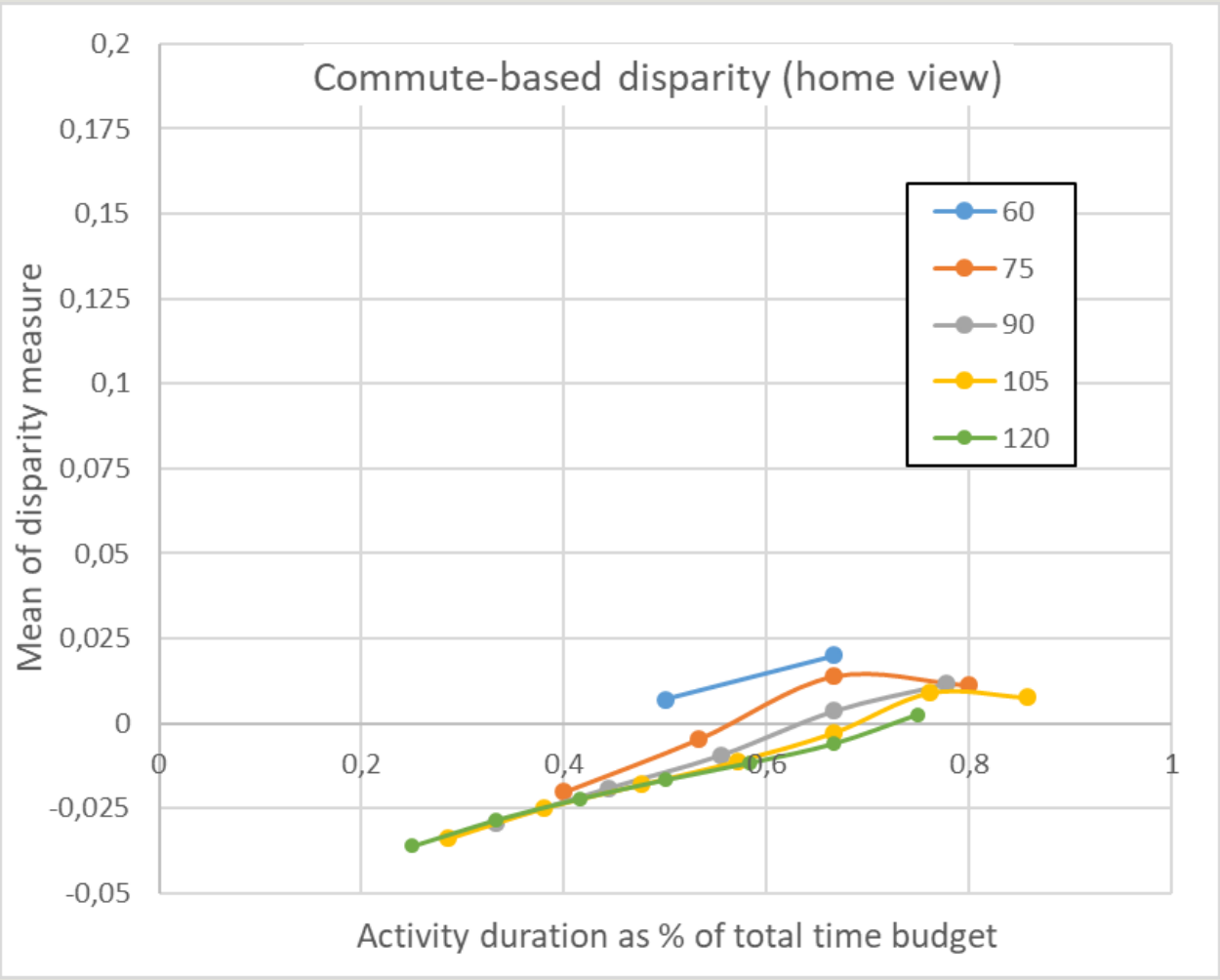
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0,8
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Activity duration as % of total time budget
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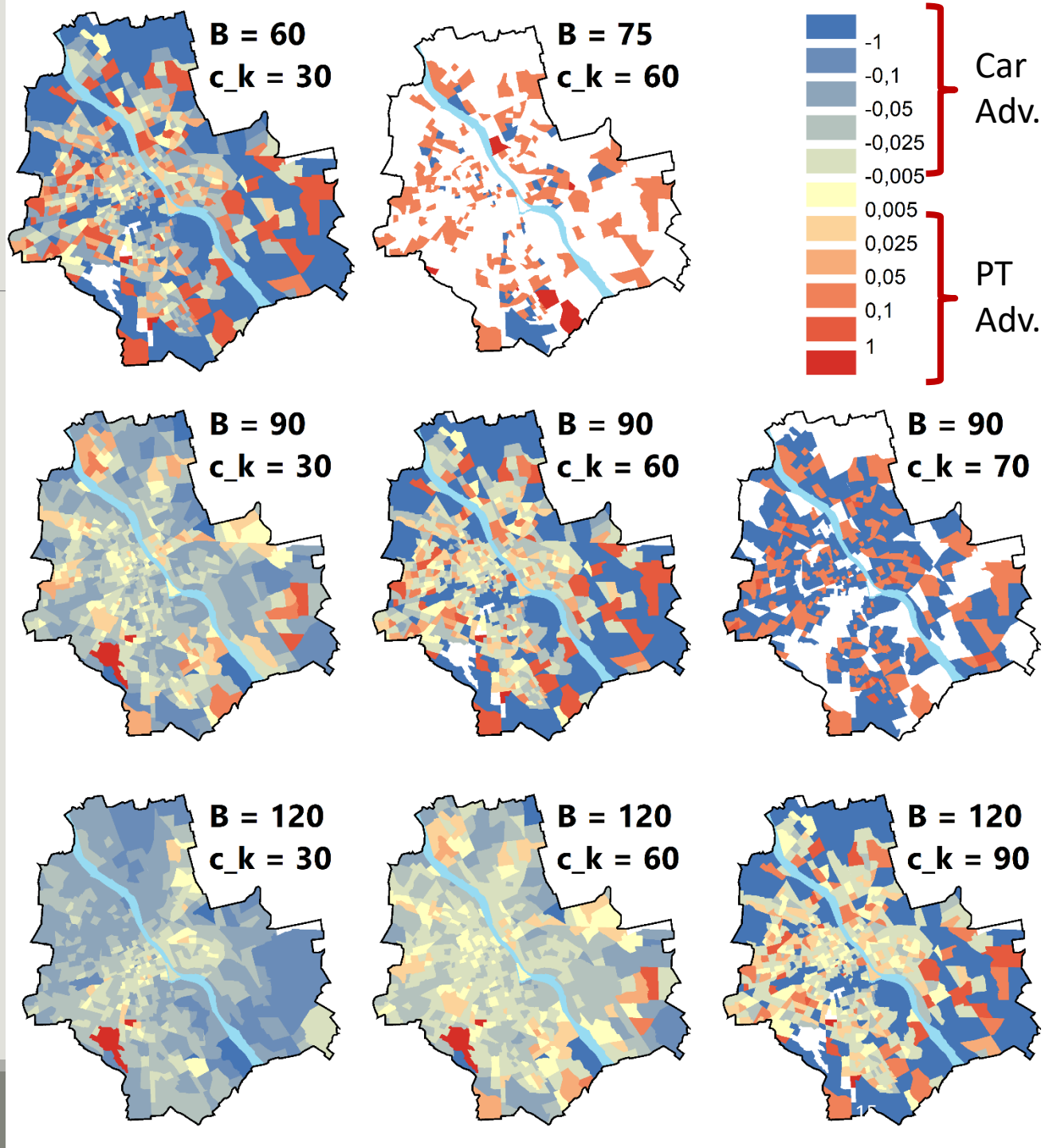
120

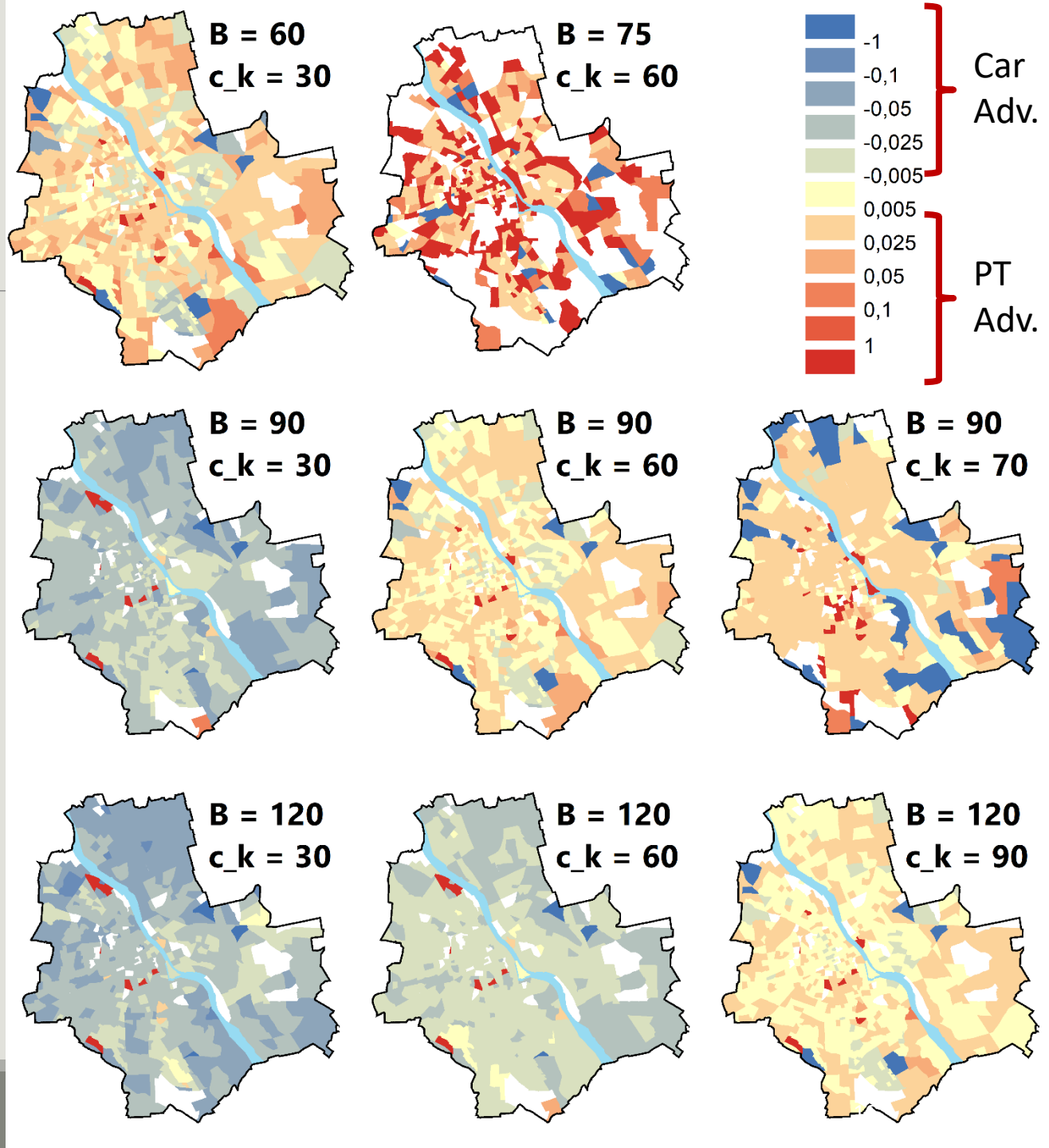
Home-based accessibility

- B = total time budget in minutes
- c_k = activity duration time in minutes



Commute-based accessibility

- Shown from home location
- B = total time budget in minutes
- c_k = activity duration time in minutes



Conclusions

- The modal disparity increasingly favors public transport as the activity duration is an increasing share of the total time budget
  - When activity duration < 50%, then better car accessibility
  - When activity duration > 60%, then better public transport accessibility
- Contrasts to other studies
  - Modal disparity in Warsaw is small
    - High car accessibility advantage in North America cities
    - High public transport advantage in Hong Kong
  - Spatial pattern of disparity reversed compared to North American cities
    - Better car accessibility in city center for most home-based scenarios, and when activity duration < 50% in commute-based scenarios
    - Better public transport accessibility in housing estates outside city center in home-based scenarios
    - Balanced car-public transport accessibility in non-housing estate areas and better public transport accessibility in housing estates in commute-based scenarios

Thank you!

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