ANALYZING THE MOBILITY CUSTOMS OF THE URBAN POPULATION USING MOBILE NETWORK DATA

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ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

INTRODUCTION

A city is more than a place in space, it is a drama in time. – Patrick Geddes

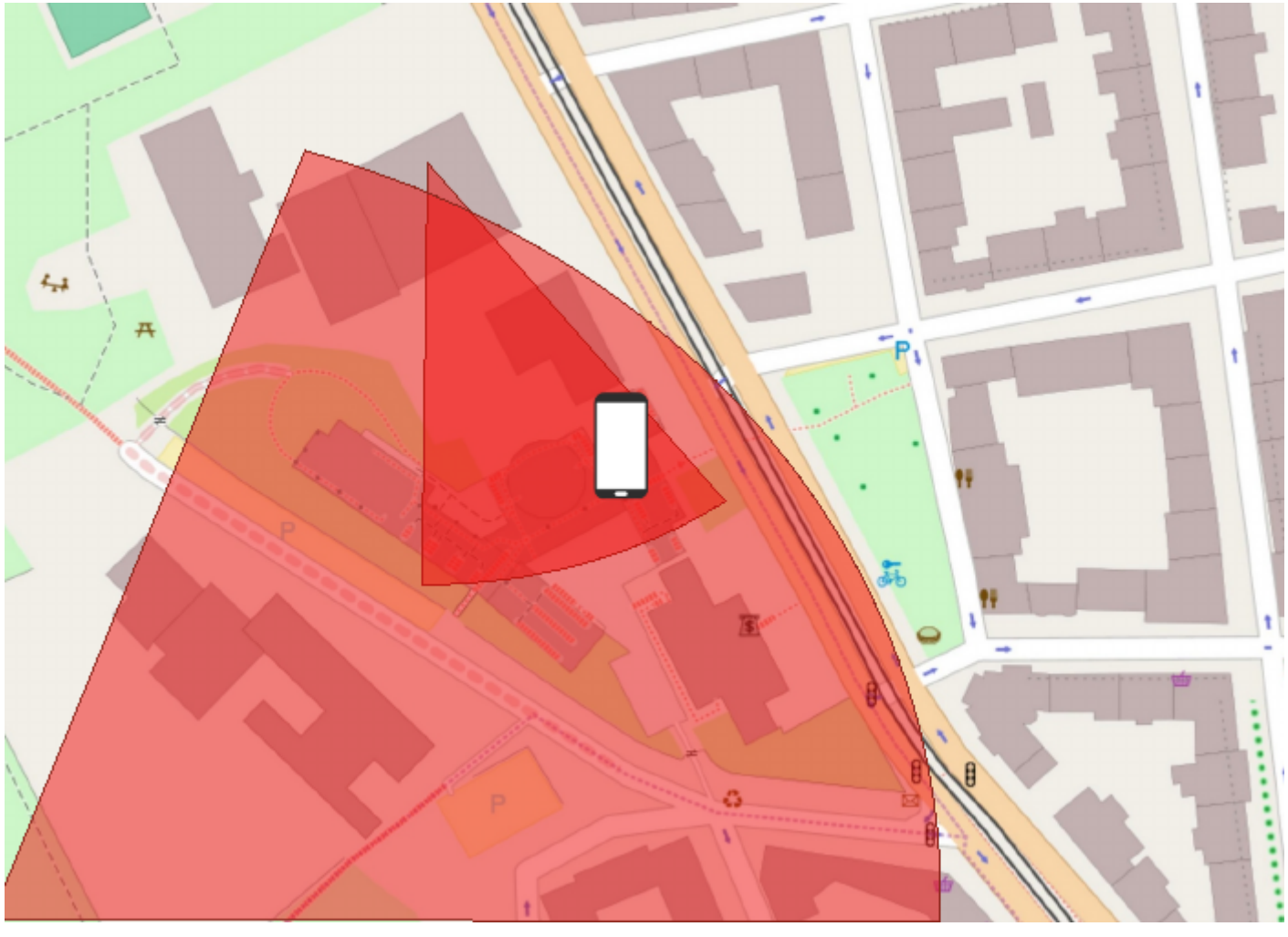
RESEARCH GOALS

- Develop methodologies to characterize the mobility patterns of the urban population quantitatively
- Implement a data processing framework for calculating the mobility indicators
  - e.g., home and work locations, Entropy, Radius of Gyration
- Enrich mobile network data with other data sources to characterize the socioeconomic status (SES)
- Design a method to analyze the relationship between the mobility and SES

CALL DETAIL RECORDS

- billed activity (calls, short messages, data transfer)
- *who*, when, where
  - *anonymized*
- additional information
  - gender, age, subscription type, type allocation code (TAC)
  - cell-map for geographical positioning

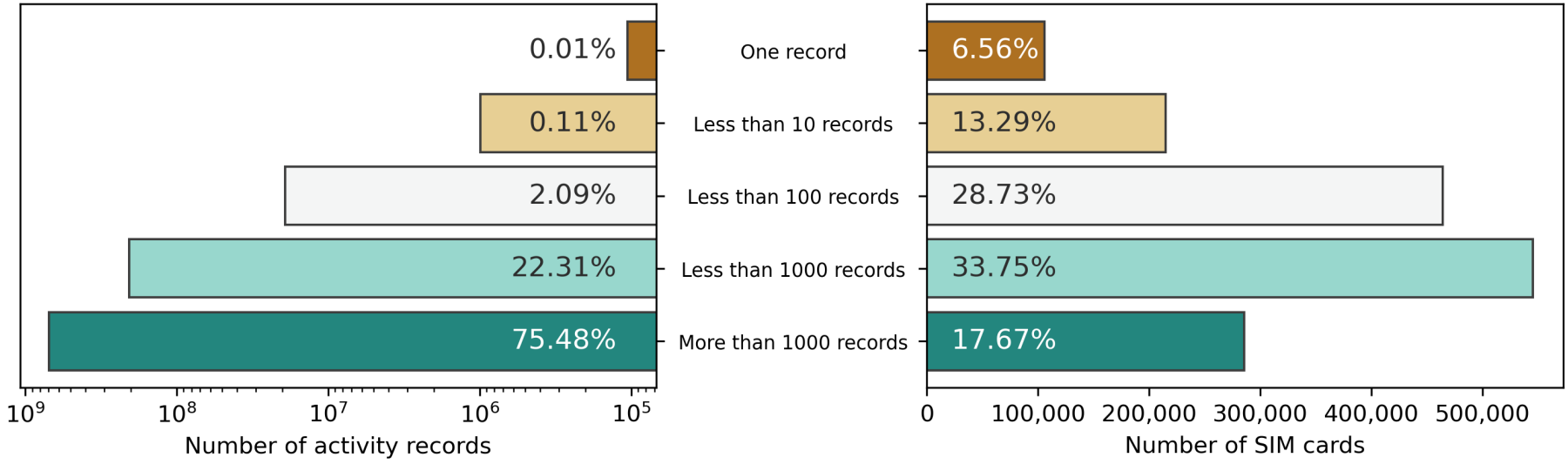
POSITIONING



overlapping cells

APRIL 2017 DATA SET

- Vodafone Hungary (market share: 25.5%[1])
- 955,035,169 records
- 1,629,275 unique SIM cards



THESIS 1: NEW METHOD FOR EVALUATION OF THE COMMUTING BASED ON MOBILE NETWORK DATA

I have designed a method to describe the commuting patterns of the population quantitatively. The method is based on the statistical detection of the home and work locations using anonymized mobile network data. I have validated the results by comparing them to census-based commuting analyses and found good agreement between the determined mobility patterns and census-based data.

HOME AND WORK LOCATIONS – METHODOLOGY

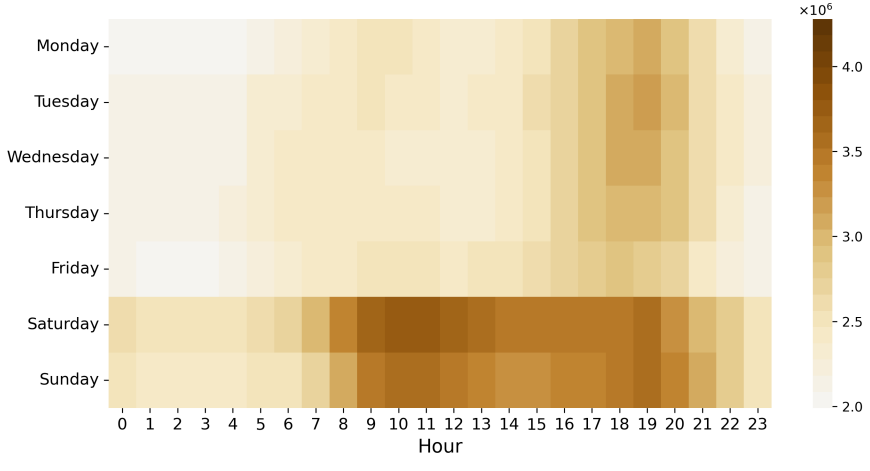
Home

- the most frequent cell where a SIM card is present
- during the evenings and the nights on workdays
- from 22:00 to 06:00
- and all day on holidays

Workplace

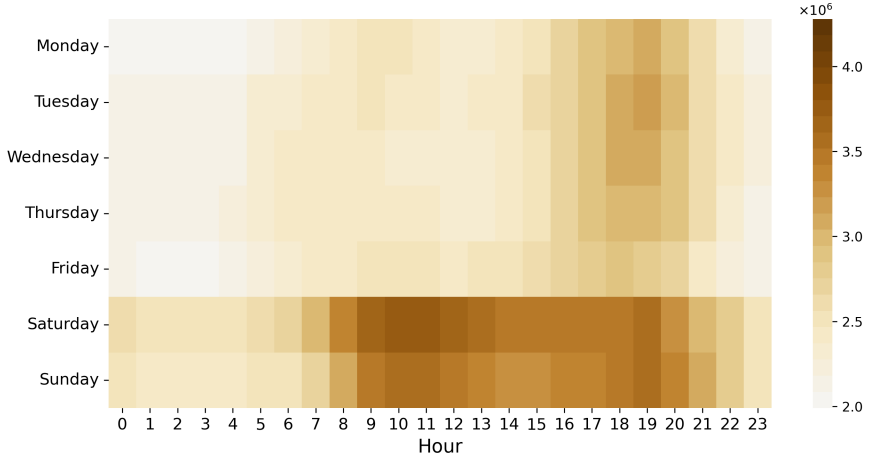
- the most frequent cell where a SIM card is present
- during working hours on workdays
- between 09:00 and 16:00

HOME AND WORK LOCATIONS – HEATMAP

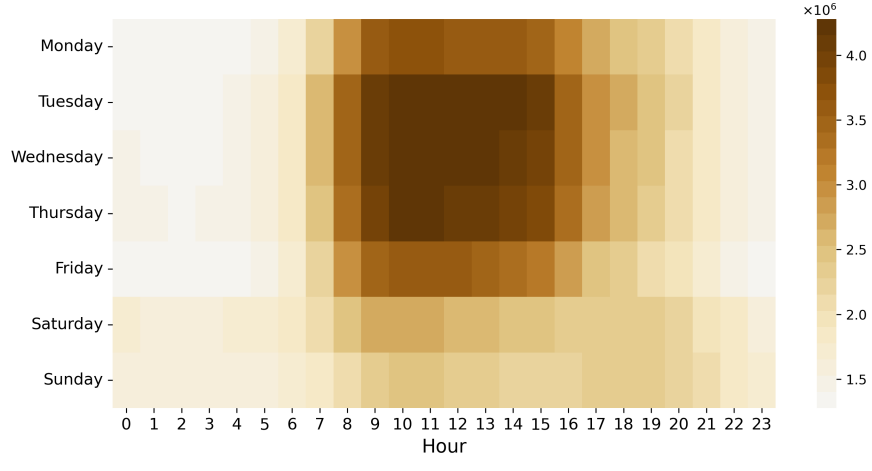


home activity

HOME AND WORK LOCATIONS – HEATMAP

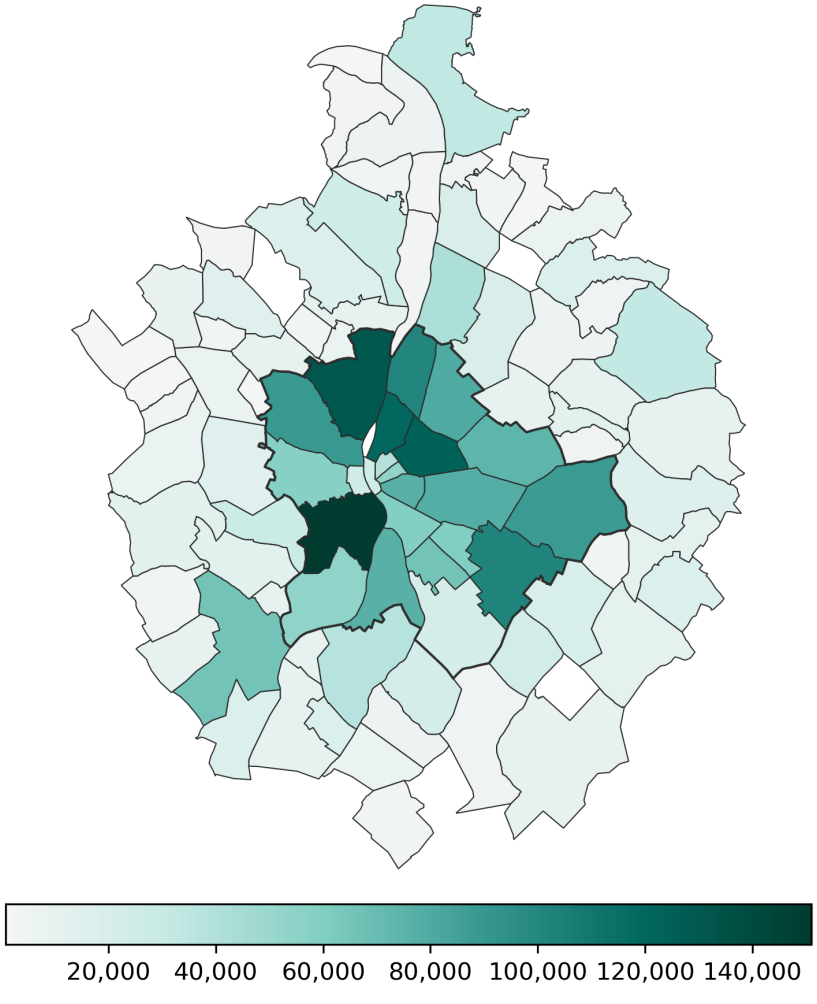


home activity

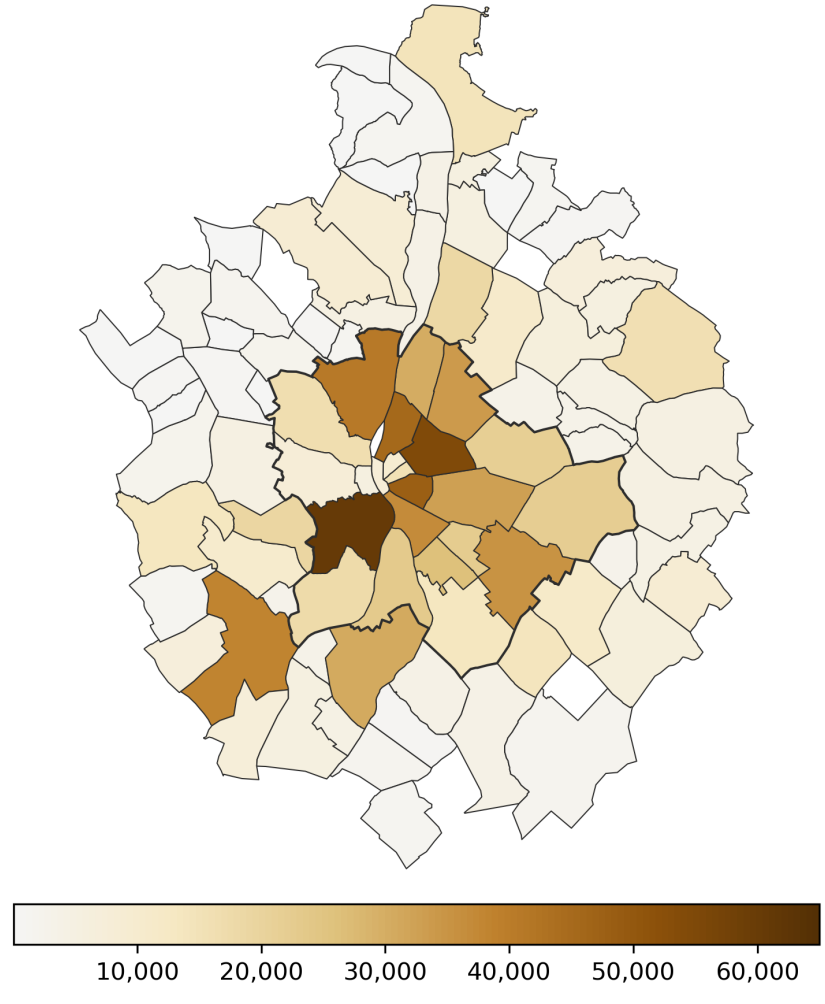


workplace activity

POPULATION

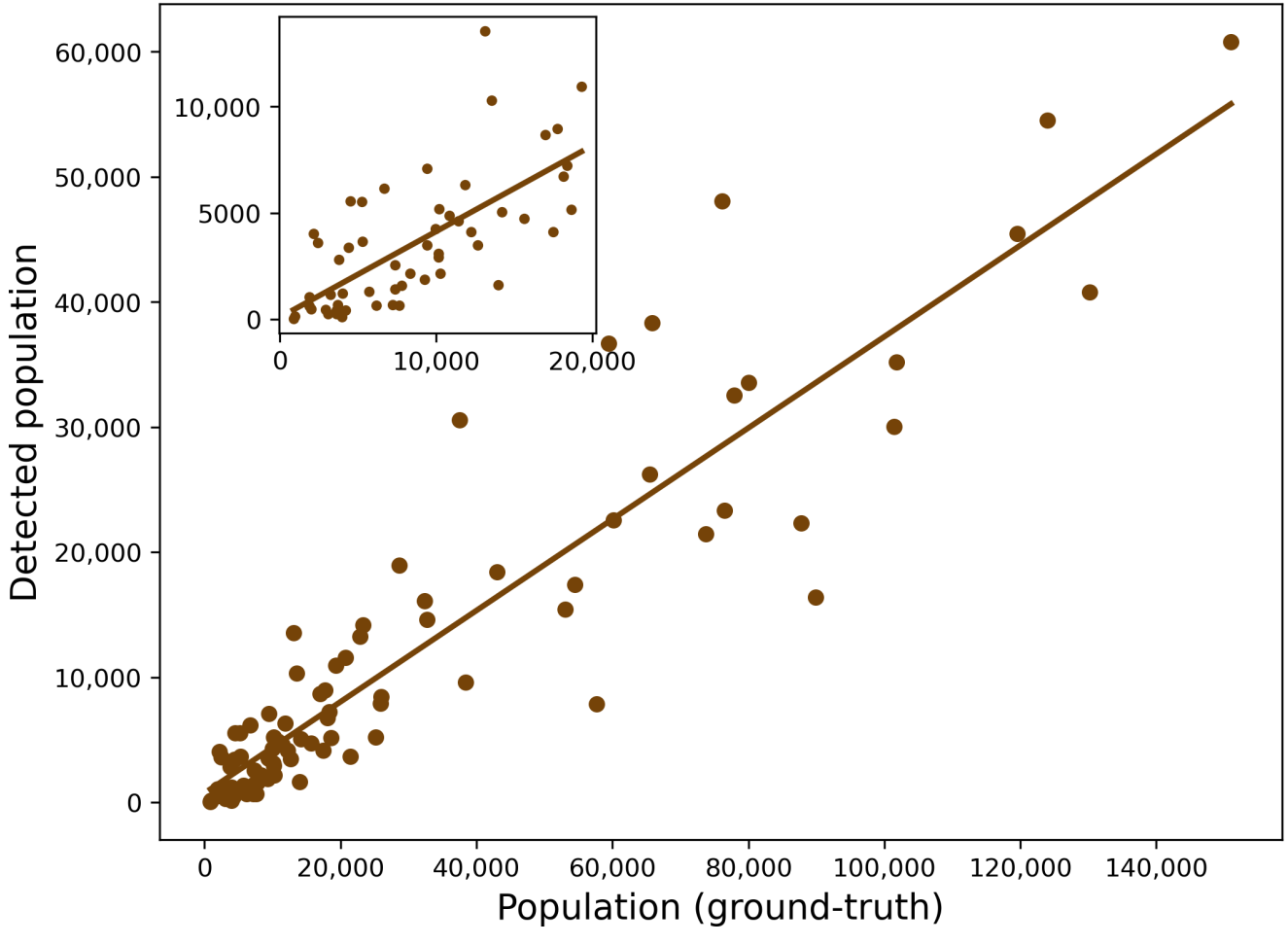


KSH (2017)[2]



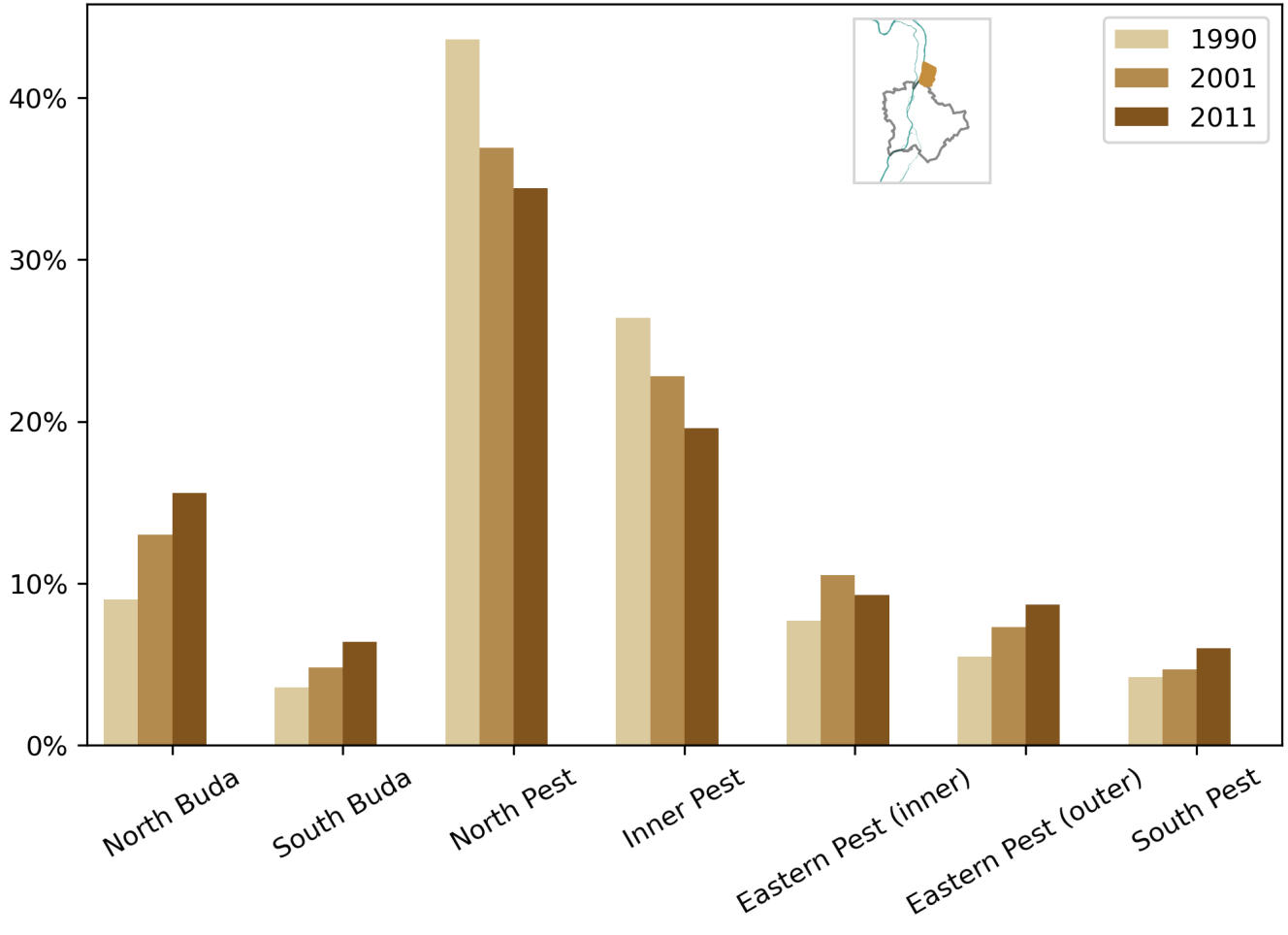
CDR (April 2017)

POPULATION – CORRELATION



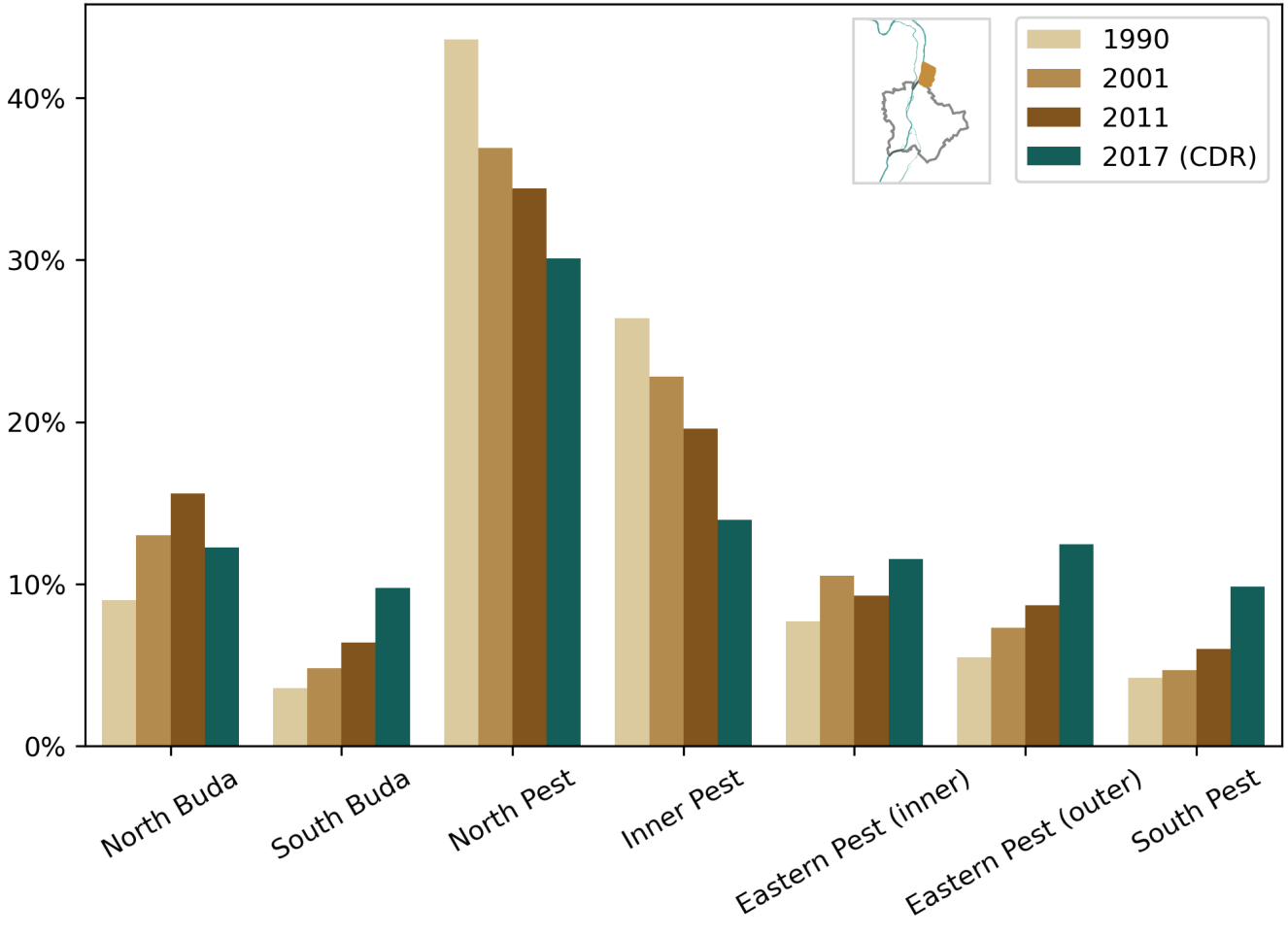
Pearson’s R is 0.9213

COMMUTING TO BUDAPEST



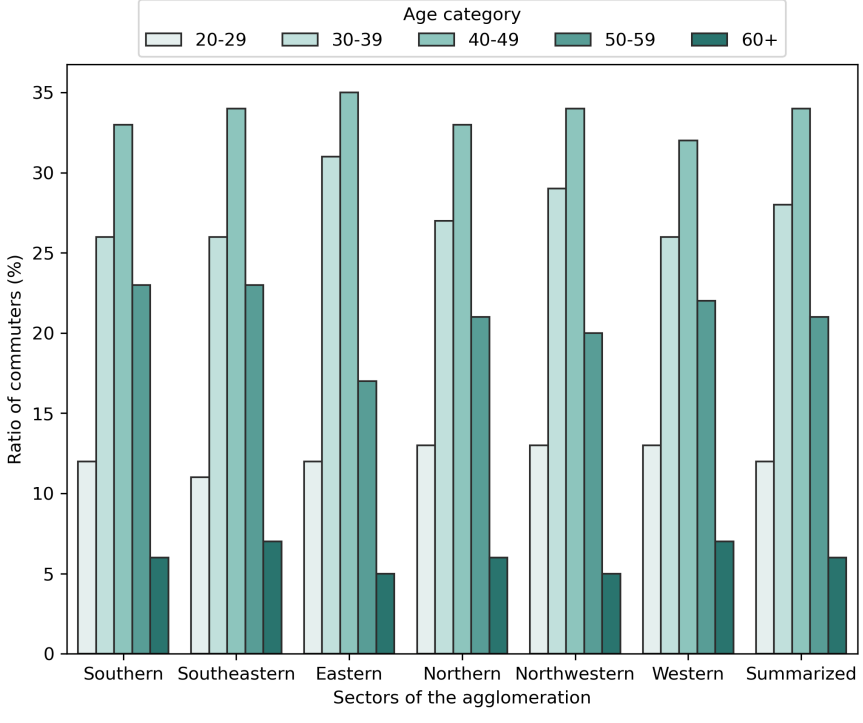
From Dunakeszi, census [3]

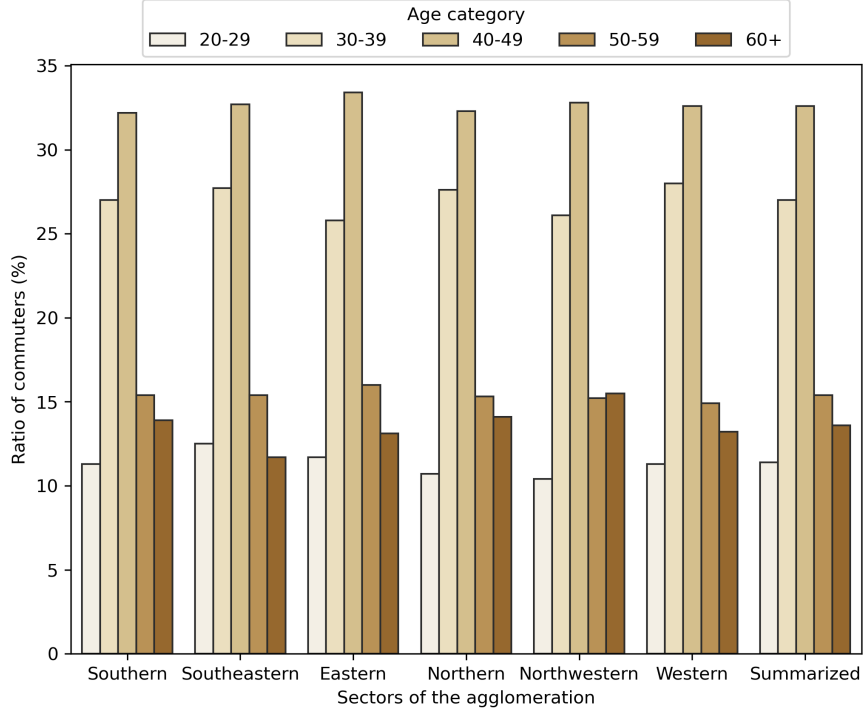
COMMUTING TO BUDAPEST



From Dunakeszi, census [3]; Pearson's R=0.9416 (CDR vs. 2011)

COMMUTING BY AGE GROUPS





Microcensus (2016)[4]

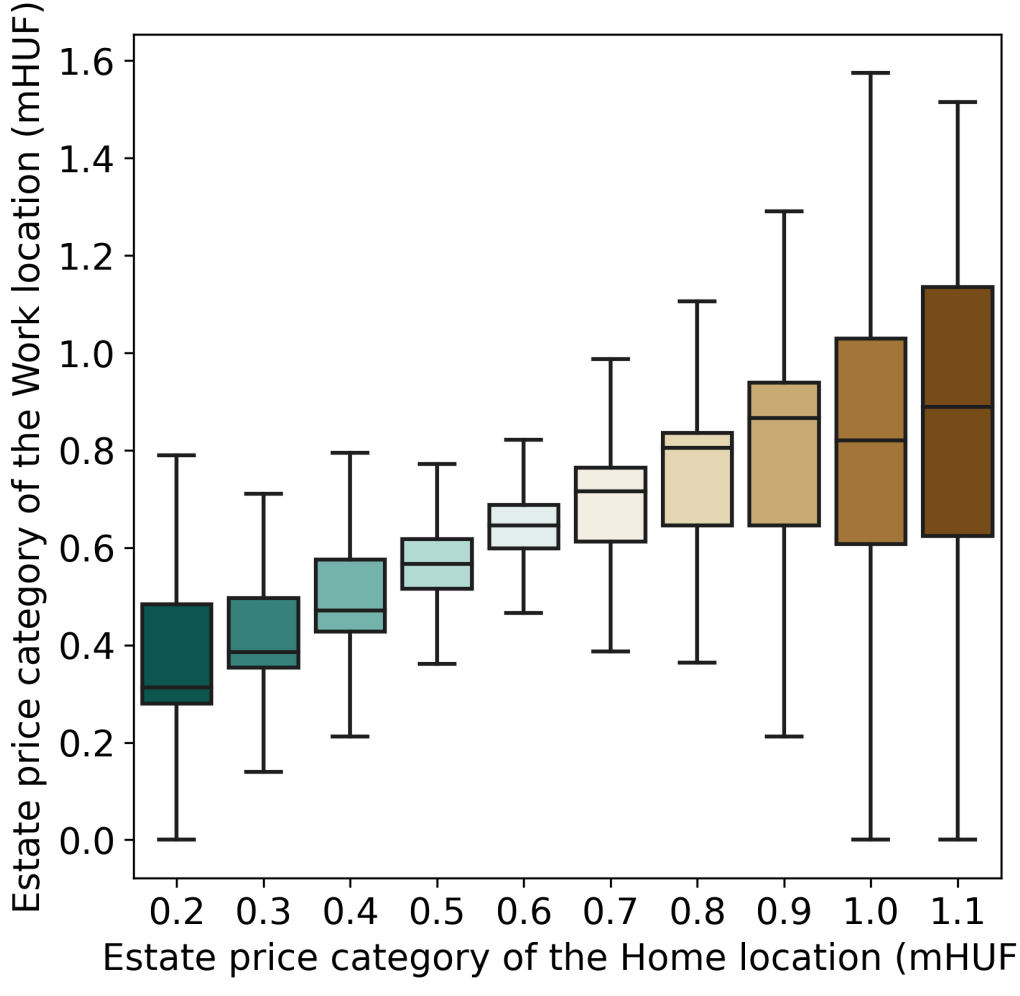
CDR (April 2017)

Pearson’s R = 0.8977

THESIS 2: CORRELATION BETWEEN HOME AND WORKPLACE PRICE-LEVELS

Using anonymous mobile network data, I have demonstrated that people living in a less expensive neighborhood usually work in a less expensive area, based on housing prices of the home and the work locations. It has also been presented that people, who live in a more expensive neighborhood, tend to work in a more expensive area.

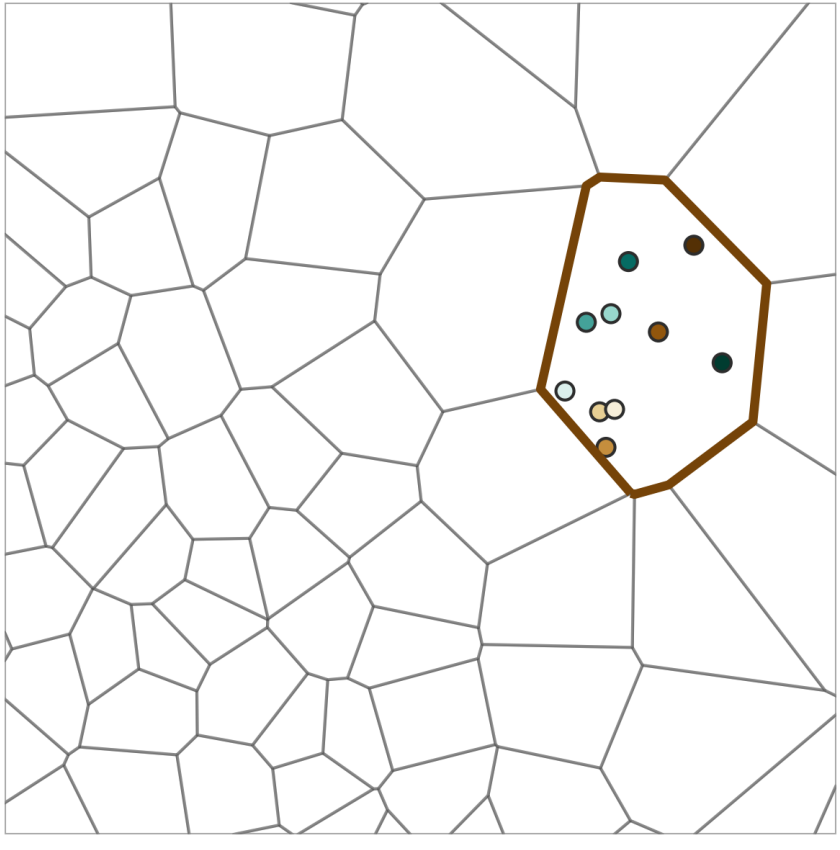
CORRELATION BETWEEN HOME AND WORKPLACE PRICE-LEVEL



THESIS 3: NEW INDICATORS FOR CHARACTERIZING MOBILITY CUSTOMS

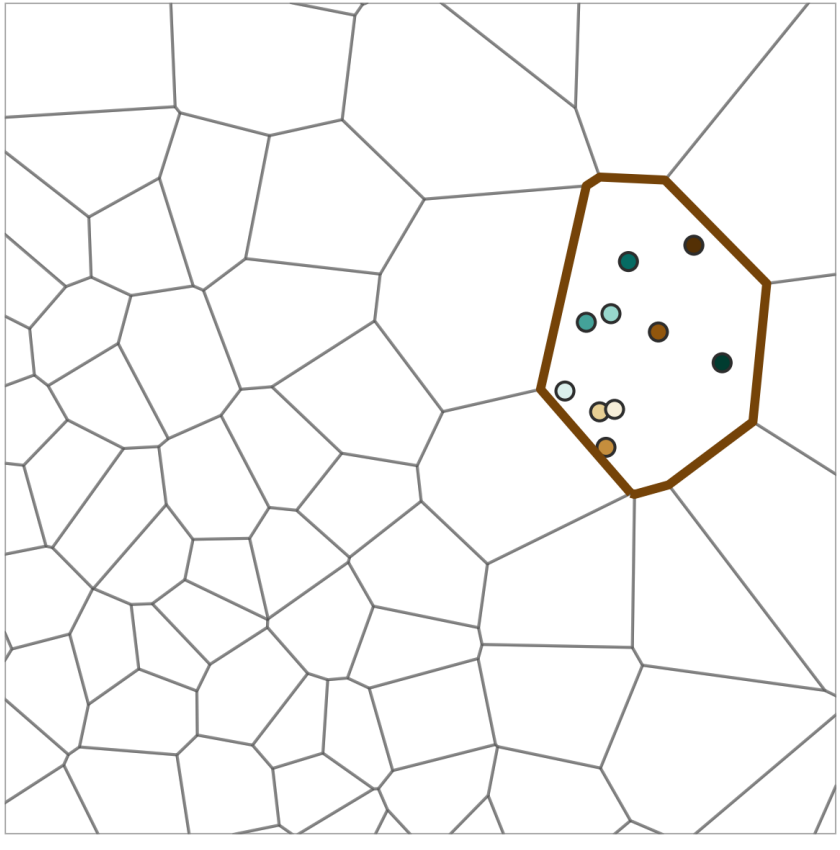
I have introduced new indicators for quantitative evaluation of wake-up time and bedtime in an urban environment. The wake-up and bedtime conditions were determined by the rate of mobile network activity in the morning and evening hours. Two subscriber aggregation methods (area and inhabitant-based) have been developed to determine the wake-up characteristics of a geographical area or a group of subscribers.

AGGREGATION METHODS

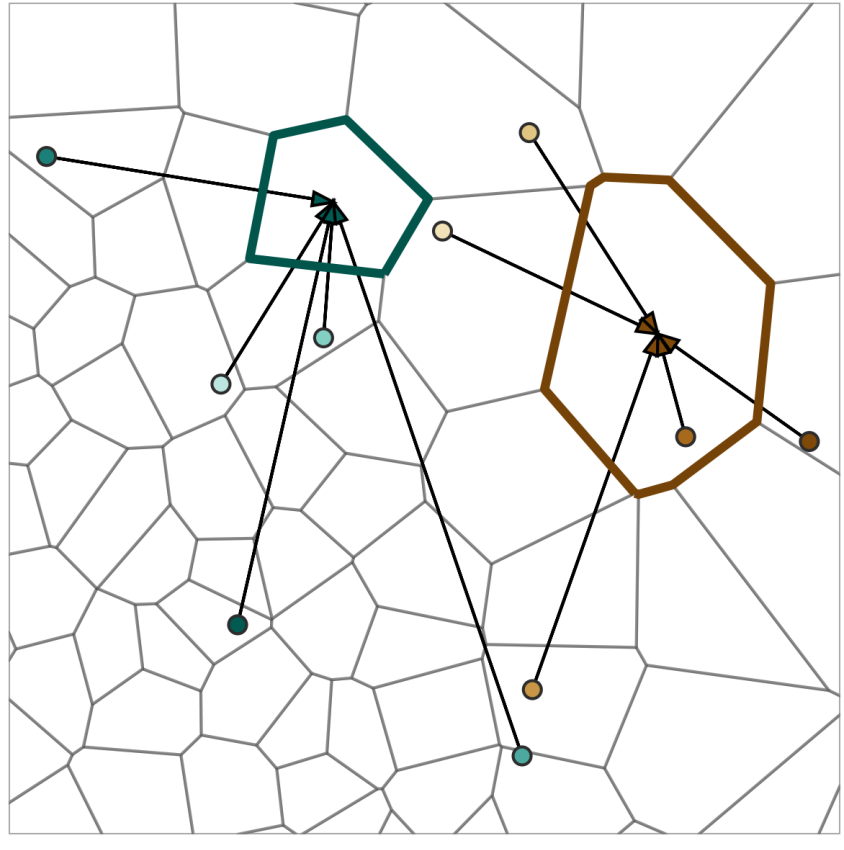


Area based

AGGREGATION METHODS

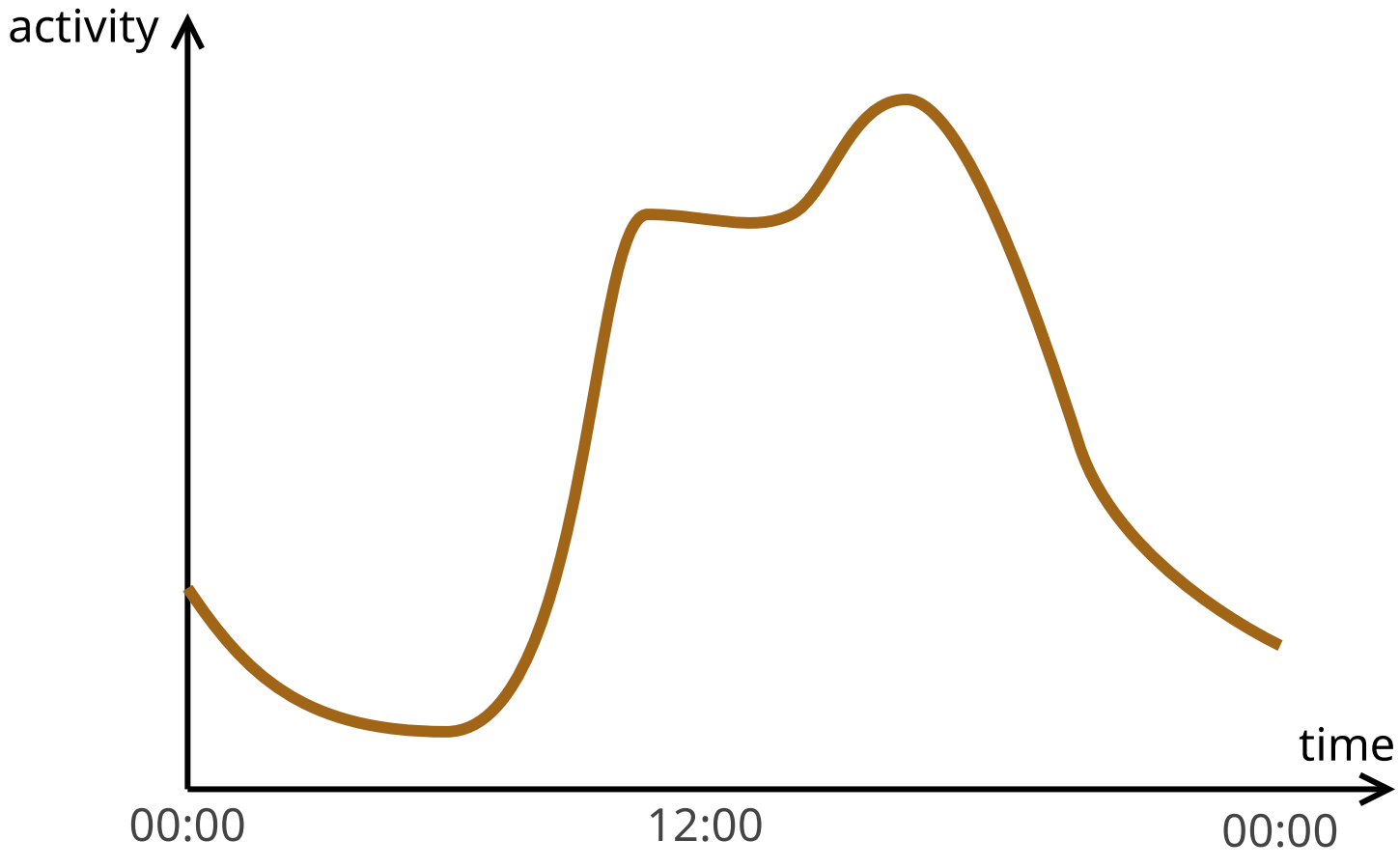


Area based

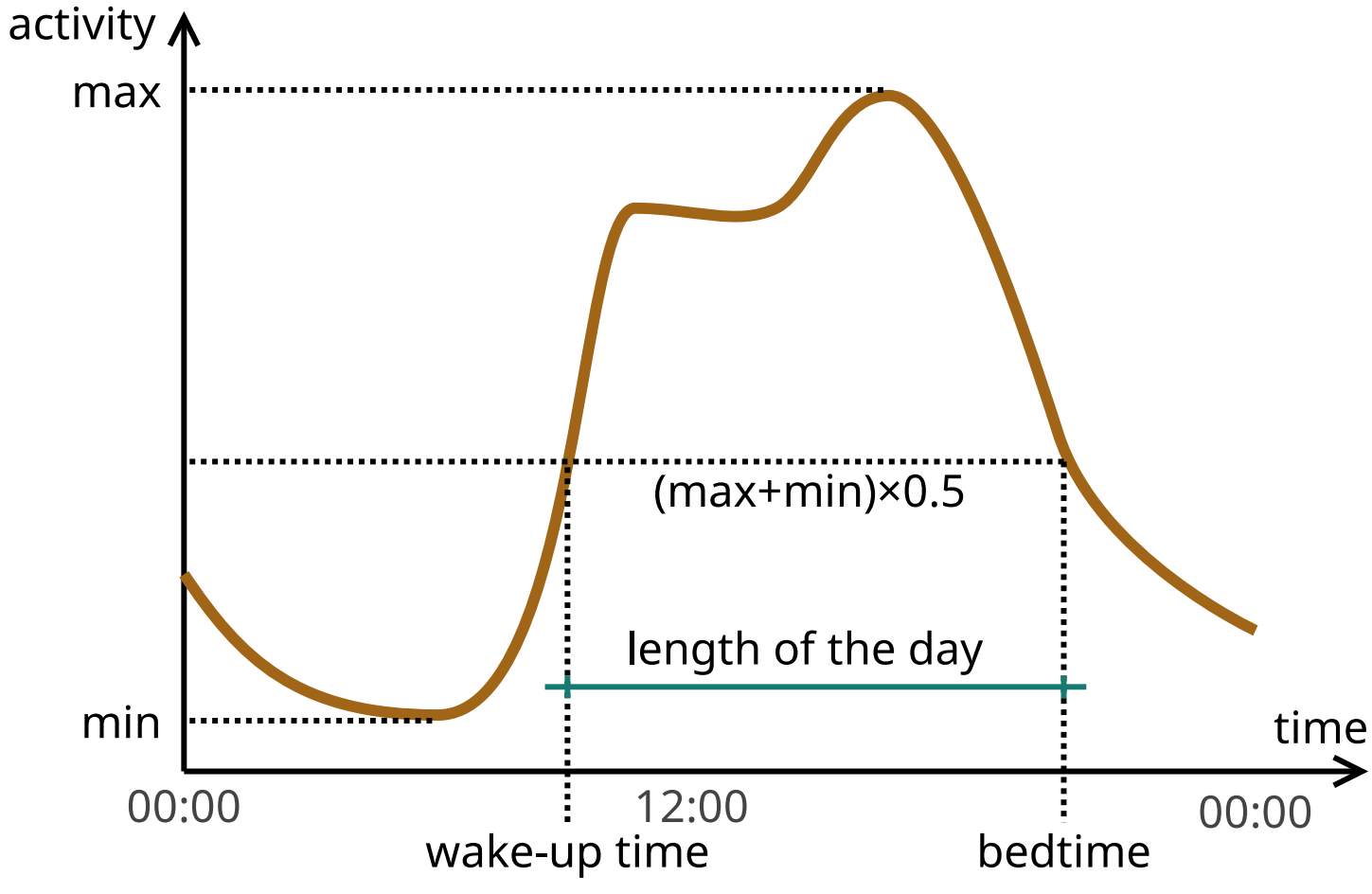


Inhabitant based

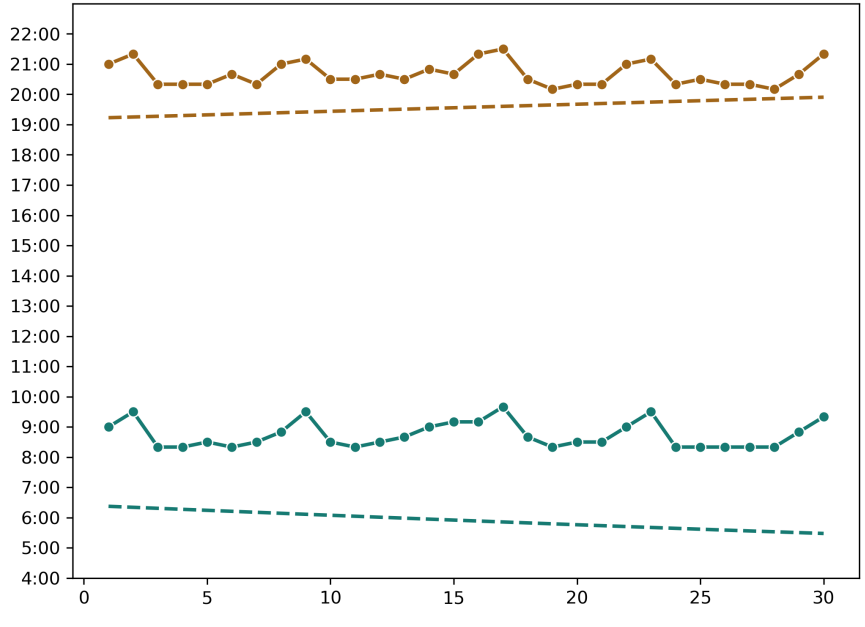
CALCULATION OF THE WAKE-UP AND THE BEDTIMES



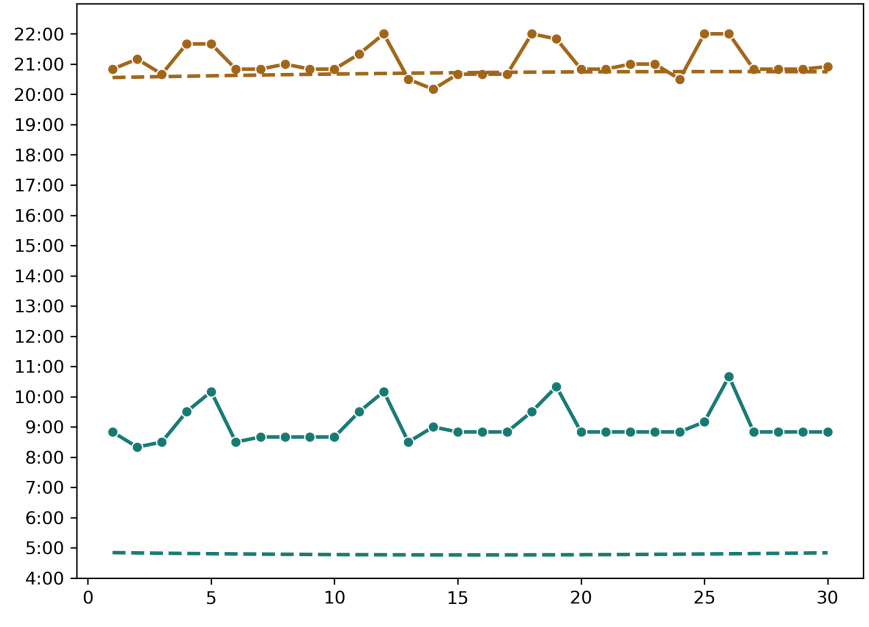
CALCULATION OF THE WAKE-UP AND THE BEDTIMES



LATER BEDTIME ON LONGER DAYS

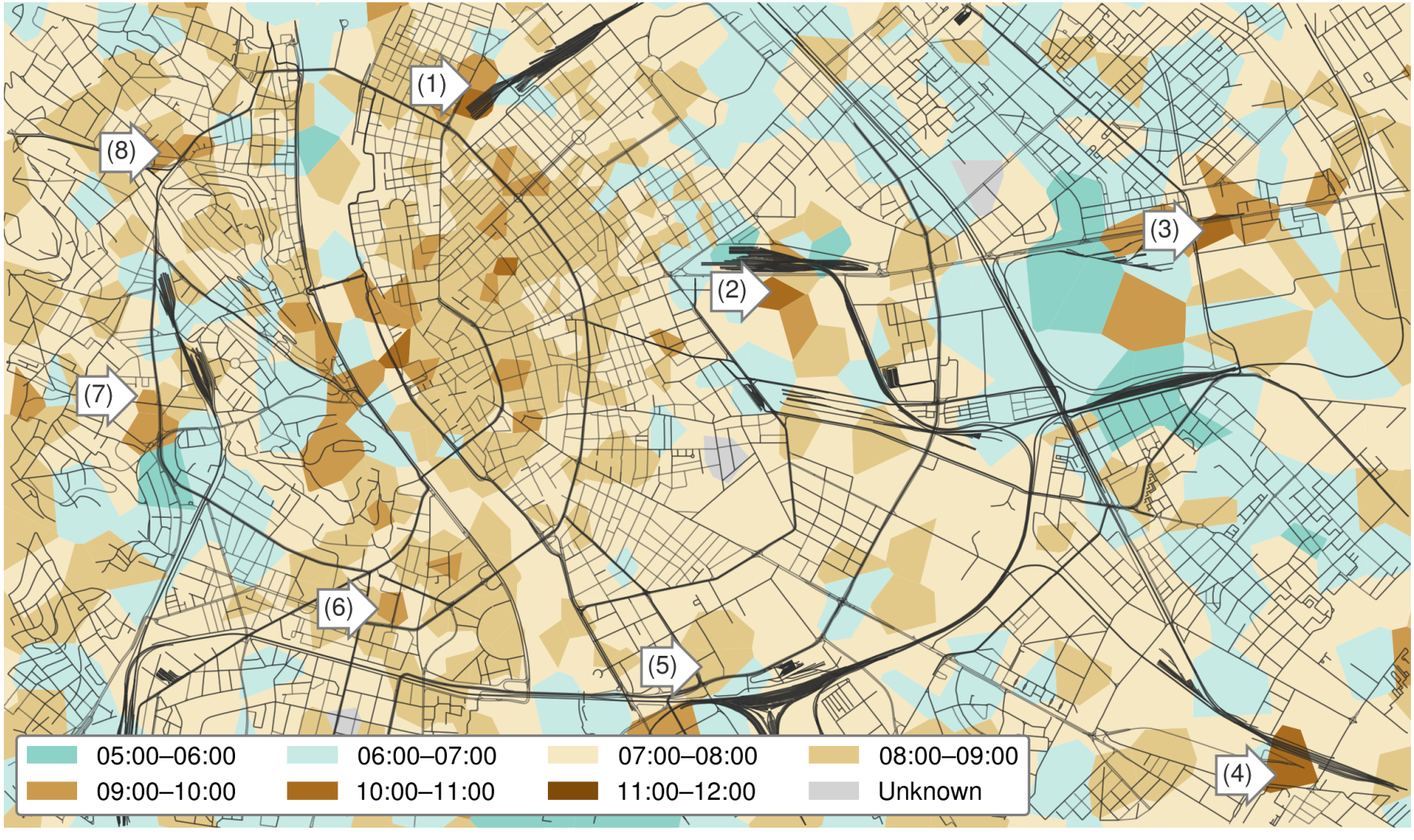


April 2017



June 2016

WHEN DO THE MALLS OPEN?



Example of the area-based approach

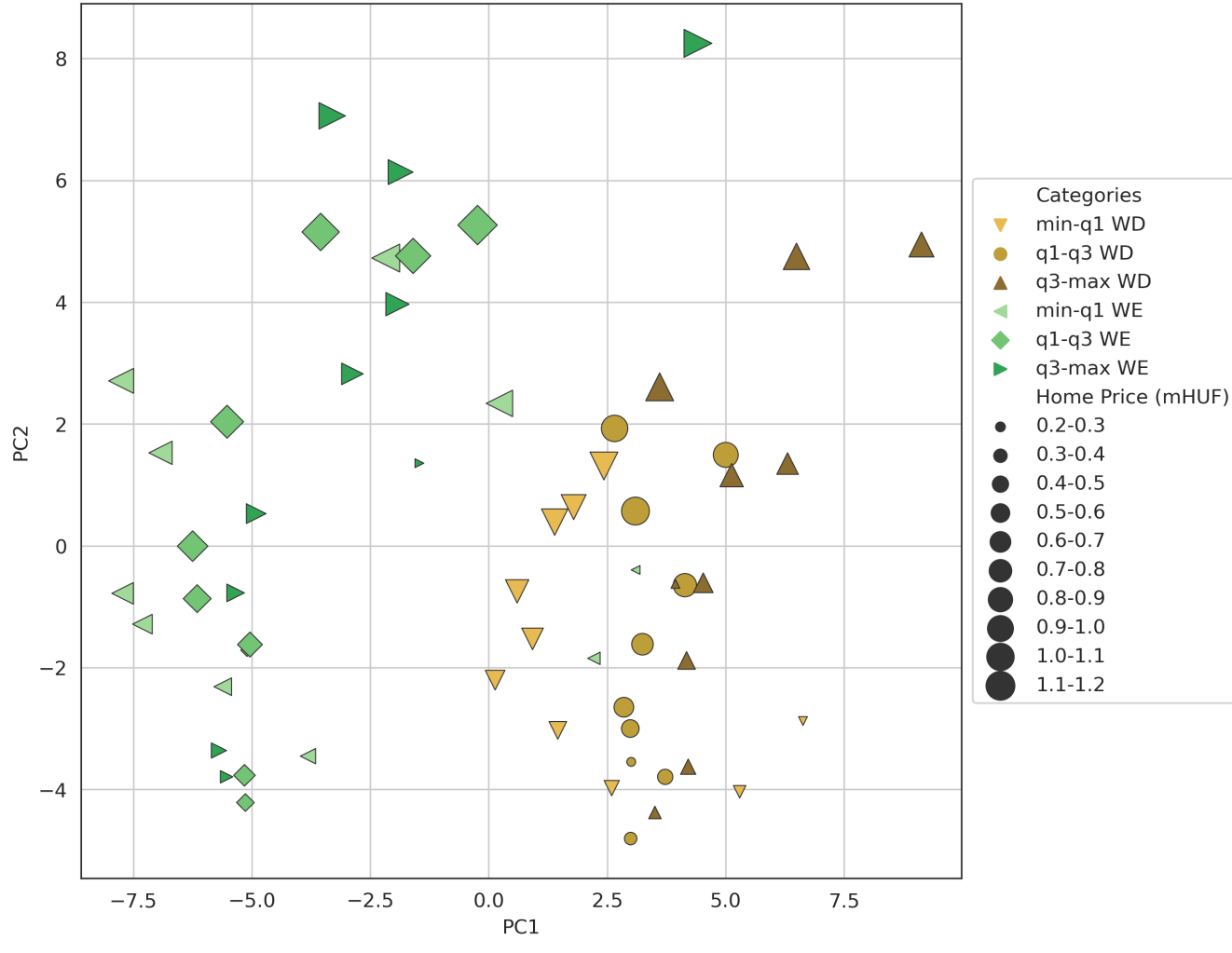
THESIS 4: NEW METHOD TO ANALYZE THE CORRELATION OF MOBILITY AND SOCIOECONOMIC STATUS

I have designed a method using Principal Component Analysis to evaluate socioeconomic status depending on the indicators of human mobility. Housing prices have been used to characterize the socioeconomic status of the population. I have found differences in the mobility customs within the different socioeconomic classes, so that the socioeconomic status can be inferred from the mobility.

INPUT OF PCA

HomePr	WorkPr	GYR_WD_0.5	GYR_WD_1.0	…	GYR_WD_20	ENT_WD_0.05	…	ENT_WD_0.95
0.2	min-Q1	0.421	0.579	…	0.000	0.000	…	0.045
0.3		0.489	0.632	…	0.000	0.000	…	0.054
…		…	…	…	…	…	…	…
1.1		0.100	0.200	…	0.000	0.000	…	0.147
0.2	Q1-Q3	0.287	0.401	…	0.012	0.000	…	0.135
…		…	…	…	…	…	…	…
1.1		0.324	0.588	…	0.000	0.026	…	0.105
0.2	Q3-max	0.051	0.092	…	0.000	0.008	…	0.121
…		…	…	…	…	…	…	…
1.1		0.625	0.813	…	0.000	0.182	…	0.091

SCATTER PLOT OF THE 2-COMPONENT PCA

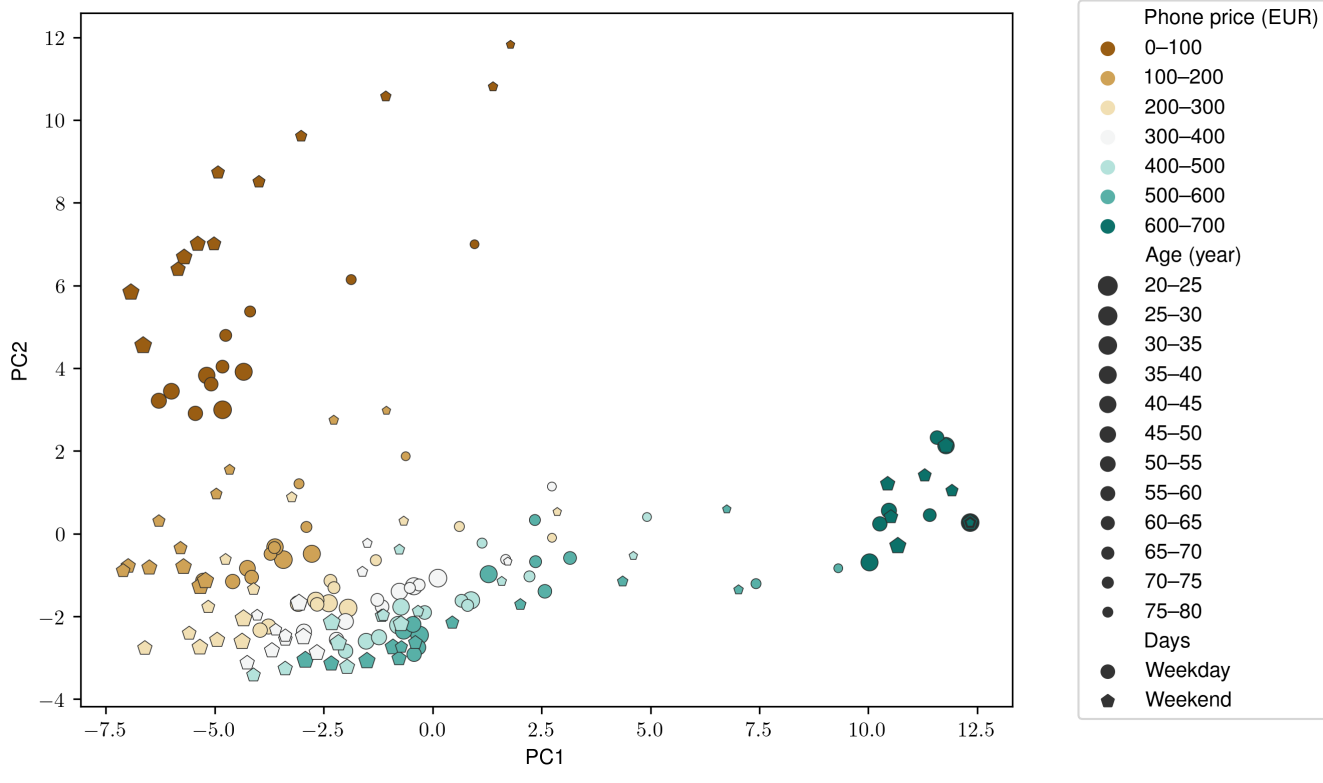


Marker size indicates the home price category, the type denotes work price category, and the color refers to Weekdays or Weekends.

THESIS 5: INTRODUCTION OF CELLPHONE PRICE AS SOCIOECONOMIC STATUS INDICATOR

I have fused cellphone prices and release dates with the mobile network data to analyze the mobility customs in contrast to the price and the age of the subscribers' cellphone. I found that the cellphone price and age are eligible to characterize a subscriber's socioeconomic status.

SCATTER PLOT OF THE 2-COMPONENT PCA

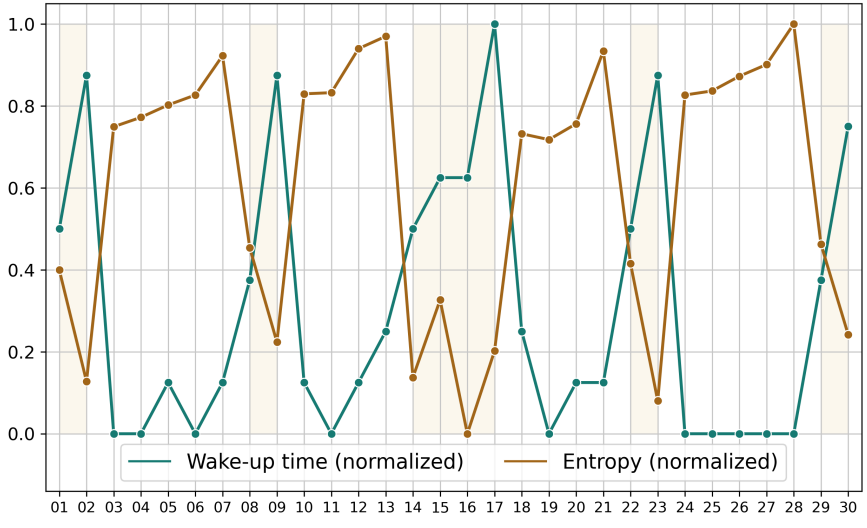


Marker size indicates subscriber age category, the color represents the phone price category, and the workdays and holidays are distinguished by the marker type.

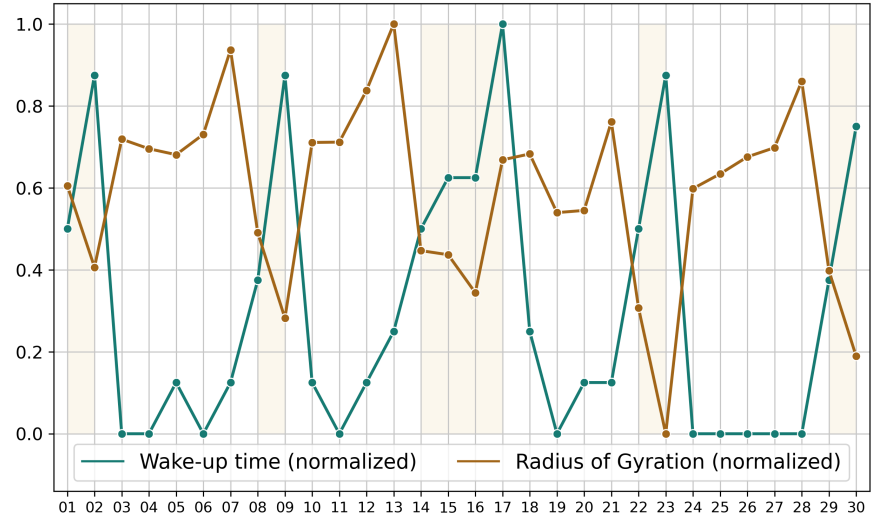
THESIS 6: THE RELATION OF WAKE-UP TIME AND SOCIOECONOMIC STATUS

I demonstrated a relationship between the wake-up time and the mobility customs, as well as the socioeconomic status. The subscribers living in less expensive apartments get up earlier than those who live in pricier neighborhoods. The same tendency holds regarding mobile phone prices: subscribers who own more expensive cellphones tend to get up later.

WAKE-UP TIME VS. MOBILITY

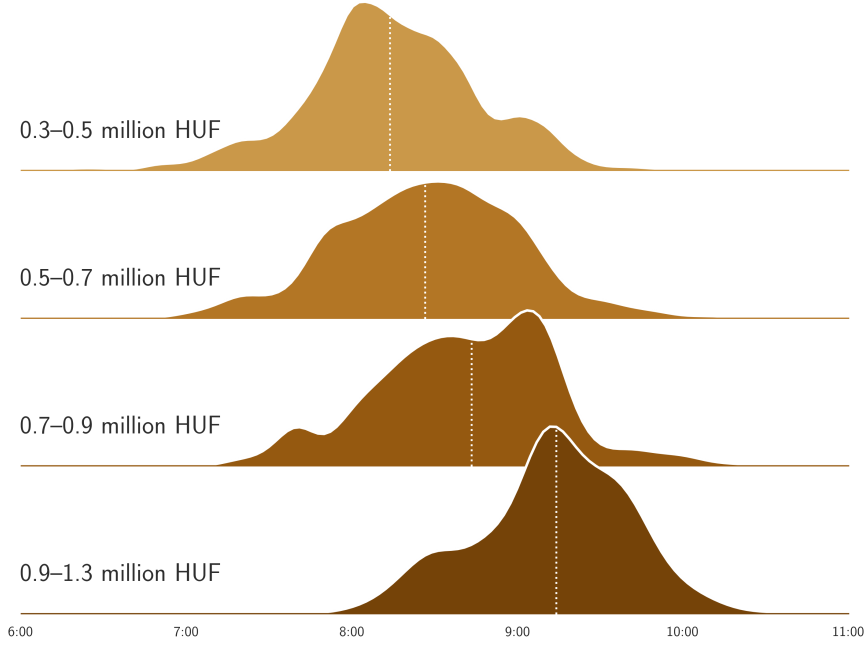


Wake-up Time in contrast of the normalized daily Entropy

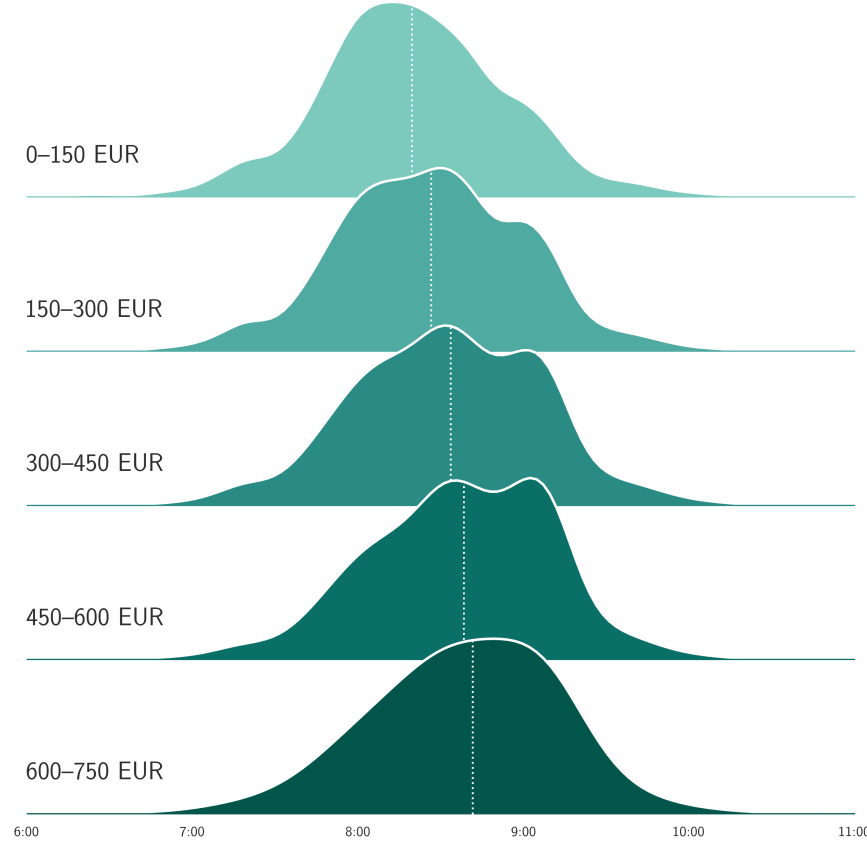


Wake-up Time in contrast of the normalized daily Radius of Gyration

WAKE-UP TIME VS. SOCIOECONOMIC STATUS



Wake-up time distribution by housing price



Wake-up time distribution by phone price

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[1] National Media and Infocommunications Authority, Hungary, "A Nemzeti Média- és Hírközlési Hatóság mobilpiaci jelentése 2015. IV. – 2019. II. negyedév," National Media and Infocommunications Authority, 23-25. Ostrom u., Budapest 1015, Hungary, Dec. 2019.

[2] Központi Statisztikai Hivatal, "Calculated population data by settlement - resident population in hungary (2017 - 2020)."

[3] M. Lakatos and G. Kapitány, "Daily mobility of labour force (commuting) and travel in budapest and in the metropolitan agglomeration based on data of the population census. Part II," *Területi Statisztika*, vol. 56, no. 2, pp. 209–239, 2016.

[4] L. Koltai and A. Varró, "Ingázás a budapesti agglomerációban," *Új munkaügyi szemle*, vol. 1, no. 3, pp. 26–37, 2020.

PUBLICATIONS

[1*] G. Pintér and I. Felde, "Evaluation of urban daily routines by using mobile phone indicators," in *2019 IEEE 13th international symposium on applied computational intelligence and informatics (SACI)*, 2019, pp. 314–319.

[2*] G. Pintér and I. Felde, "Evaluating the effect of the financial status to the mobility customs," *ISPRS International Journal of Geo-Information*, vol. 10, no. 5, p. 328, 2021.

[3*] G. Pintér and I. Felde, "Analyzing the behavior and financial status of soccer fans from a mobile phone network perspective: Euro 2016, a case study," *Information*, vol. 12, no. 11, p. 468, 2021.

[4*] G. Pintér and I. Felde, "Awakening city: Traces of the circadian rhythm within the mobile phone network data," *Information*, vol. 13, no. 3, p. 114, 2022.

THANK YOU FOR THE ATTENTION!