City monitoring with travel demand "momentum" vector fields: theoretical and empirical findings

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Outline

- Introduction
- Methodology
  - Time-geographic 3D representation
  - Generation of vector field
  - Projecting travel demand
- Study area and data
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  - Real-time taxi data in Beijing, China
- Results and discussion
  - Visual analytic analysis
  - Travel demand pattern analysis
- Conclusion and future work

Introduction

▶ How to incorporate human mobility data into assessment of urban systems?
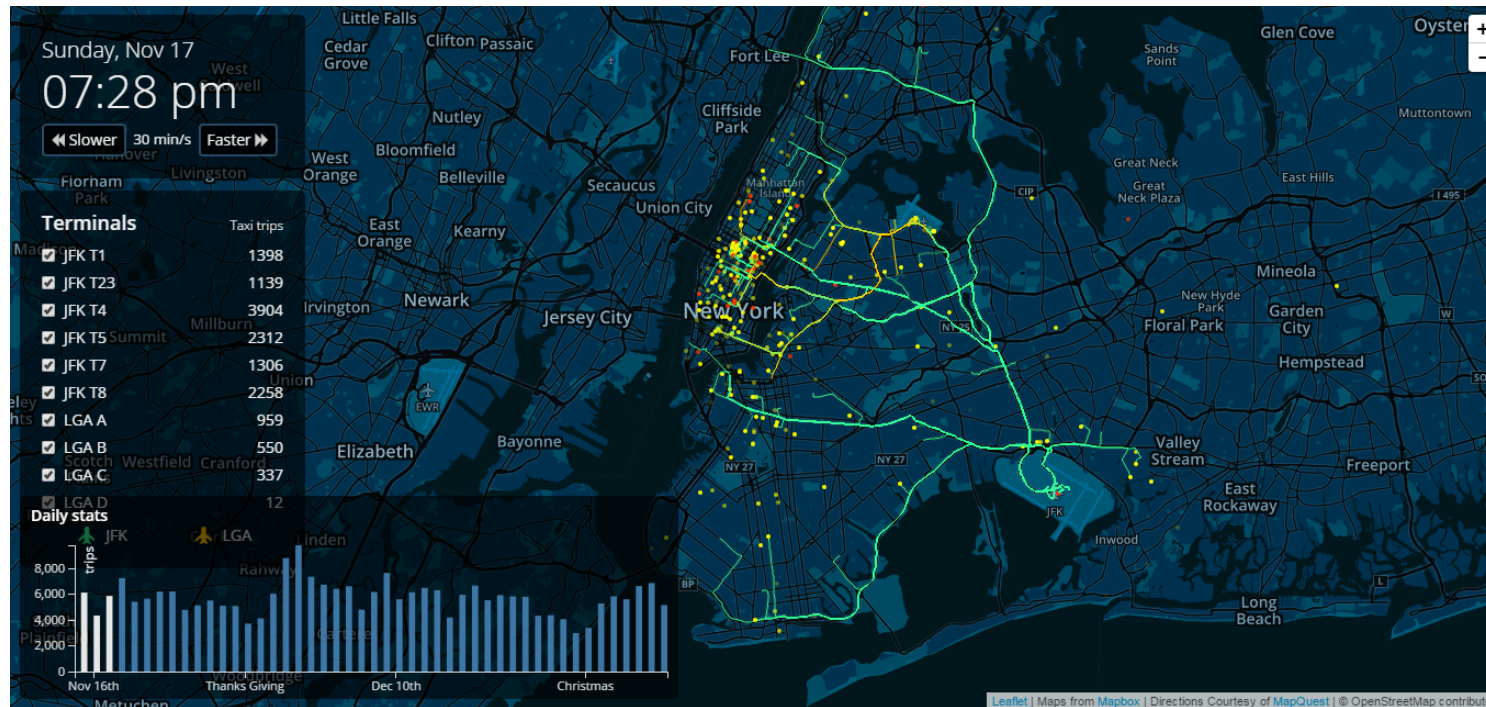
New York taxi visualization (source: http://taxi.imagework.com)

Introduction (cont.)

- Goal 1: Propose a population-based vector field for visualizing time-geographic travel demand;

- Goal 2: Theoretical and empirical verification using travel data;

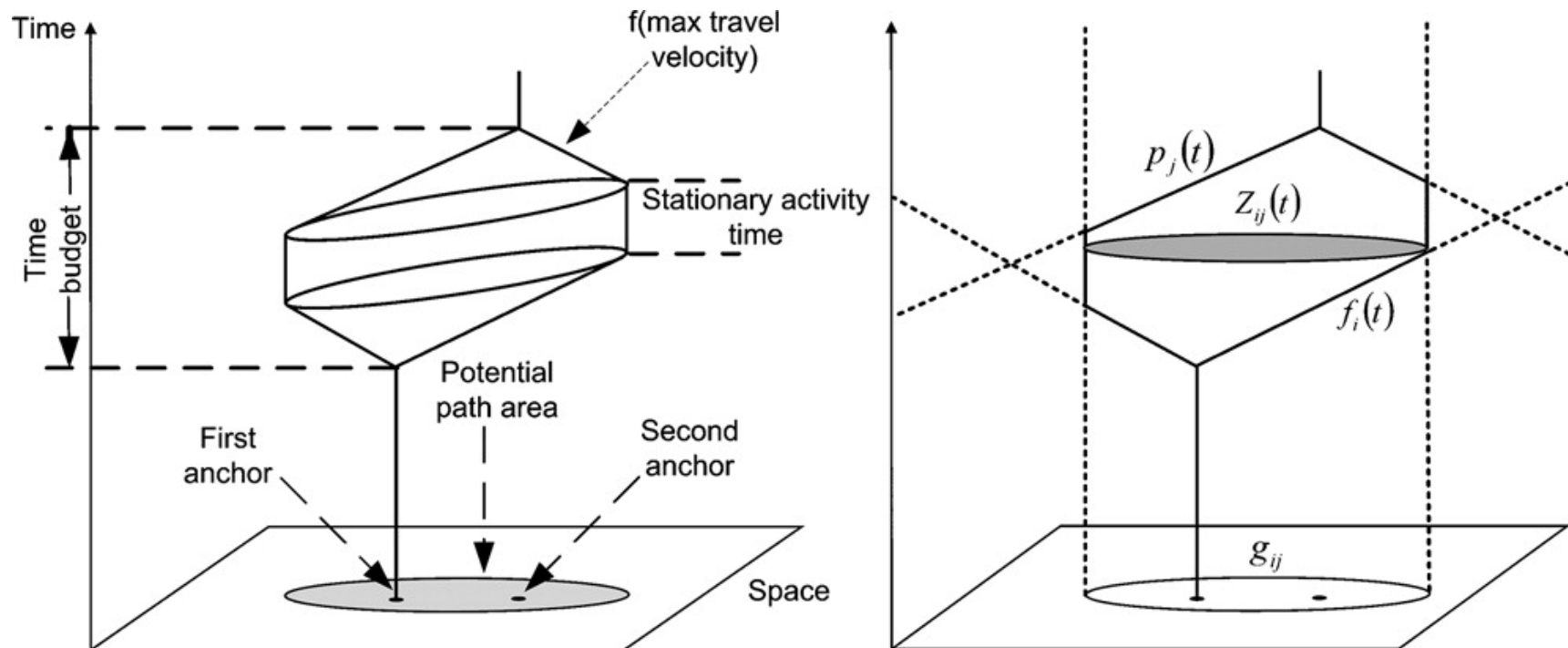- Goal 3: Develop an integrated 3D analytical GIS package.

Introduction (cont.)

- Time geography by Hägerstrand (1970)
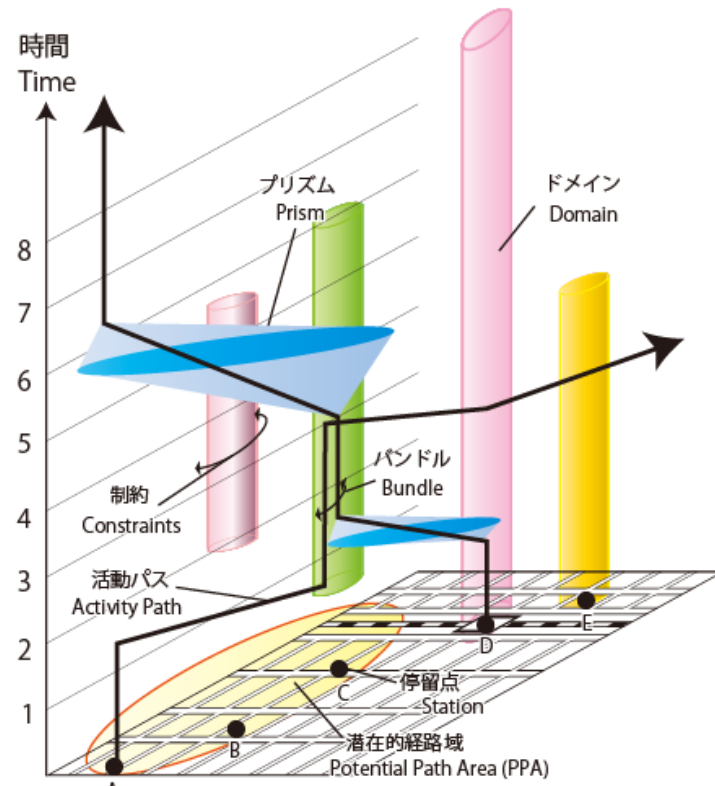

Source: https://en.wikipedia.org/wiki/Time_geography

Introduction (cont.)

▶ Studies on travel behavior and demand patterns are limited to understanding *individuals*' activity patterns

Miller, H. J., Bridwell, S. A., 2009. A field-based theory for time geography. *Annals of the Association of American Geographers*, 99(1), 49-75.
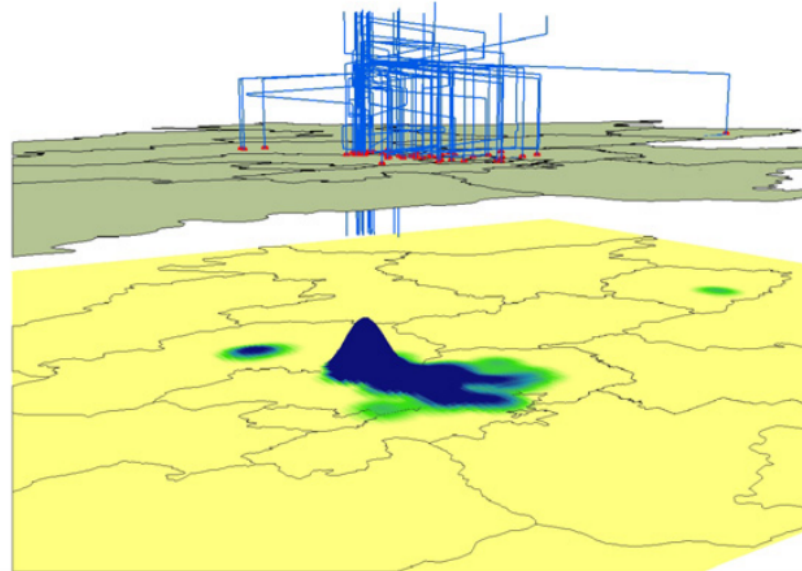
Introduction (cont.)

▶ Studies on travel behavior and demand patterns lack *directionality* at a population level.
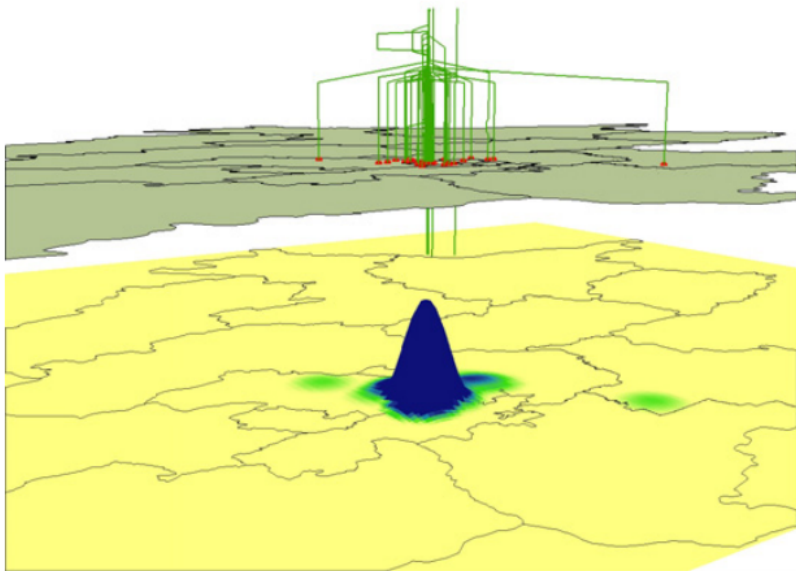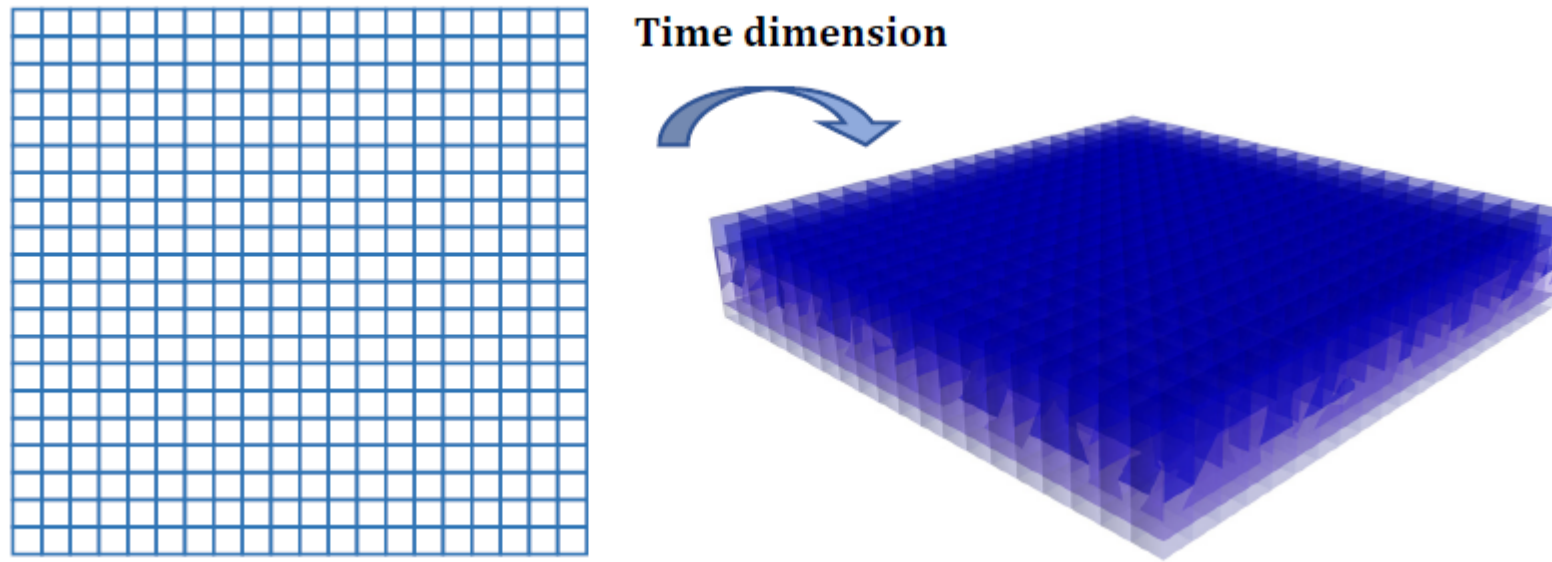

(a) Neighbourhood A   (b) Neighbourhood B

Chen, J., Shaw, S.-L., Yu, H., Lu, F., Chai, Y., Jia, Q., 2011. Exploratory data analysis of activity diary data: a space-time GIS approach. *Journal of Transport Geography* 19 (3), 394-404.

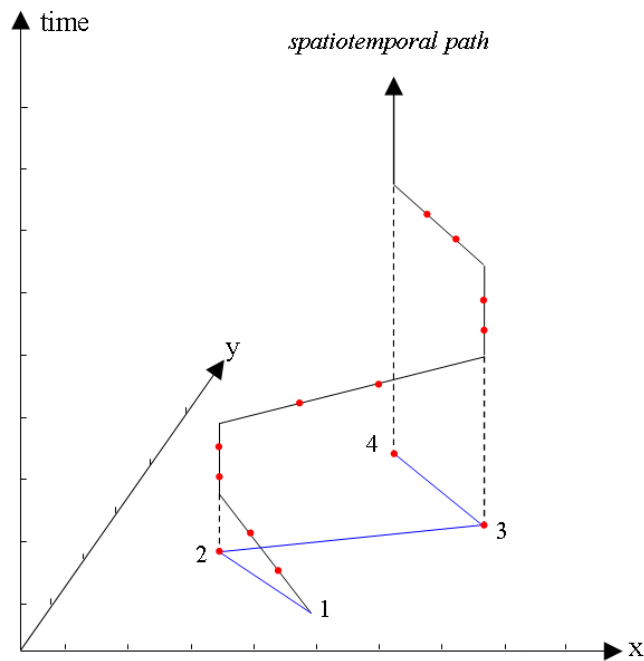# Methodology

▶ Time-geographic 3D representation of urban space

Time dimension
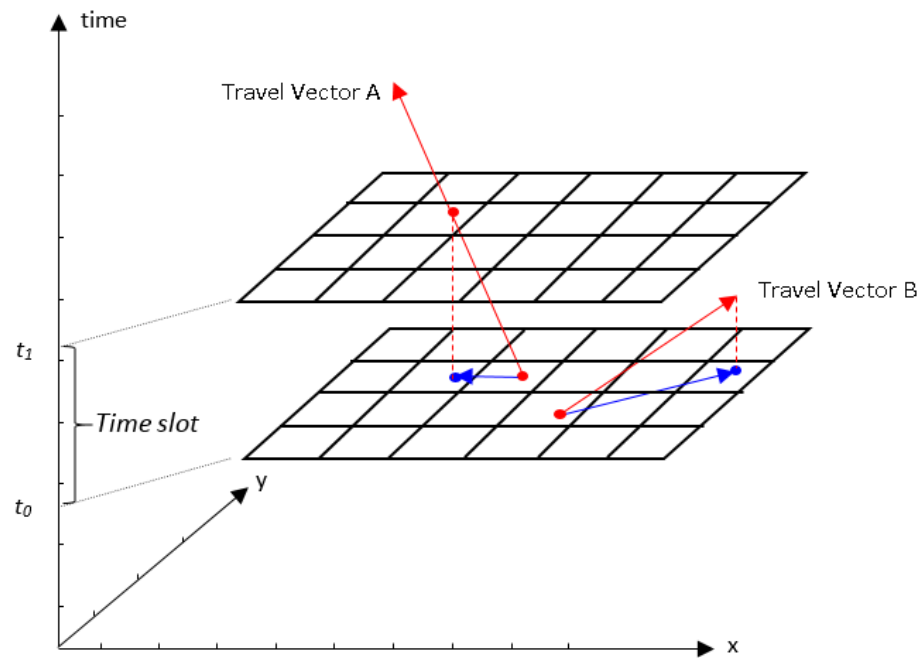
Time-geographic 3D representation of urban space

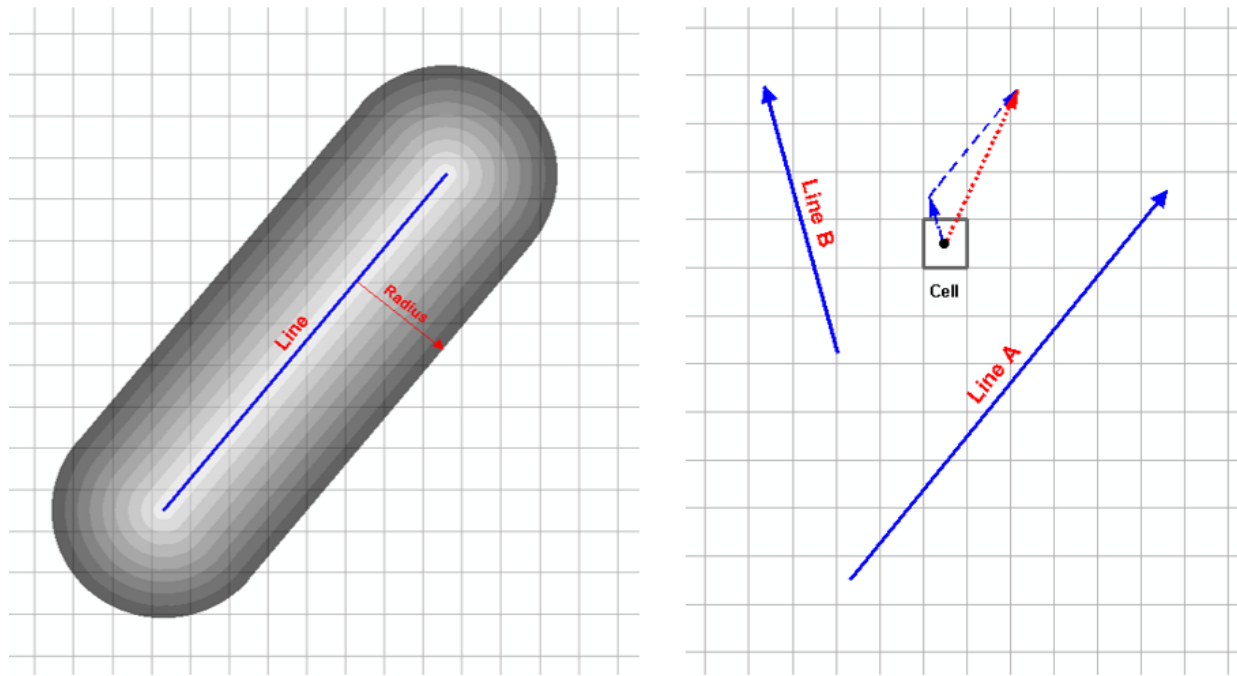# Methodology (cont.)

- Discretization of travel trajectory

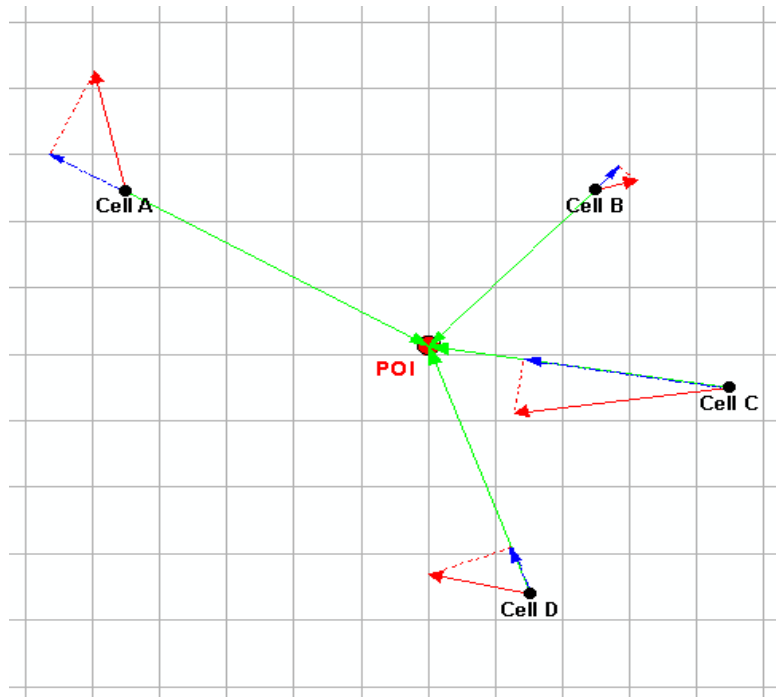Travel vector splitting by time slot

Methodology (cont.)

- Generation of vector field

How line based vector kernel density works

Methodology (cont.)
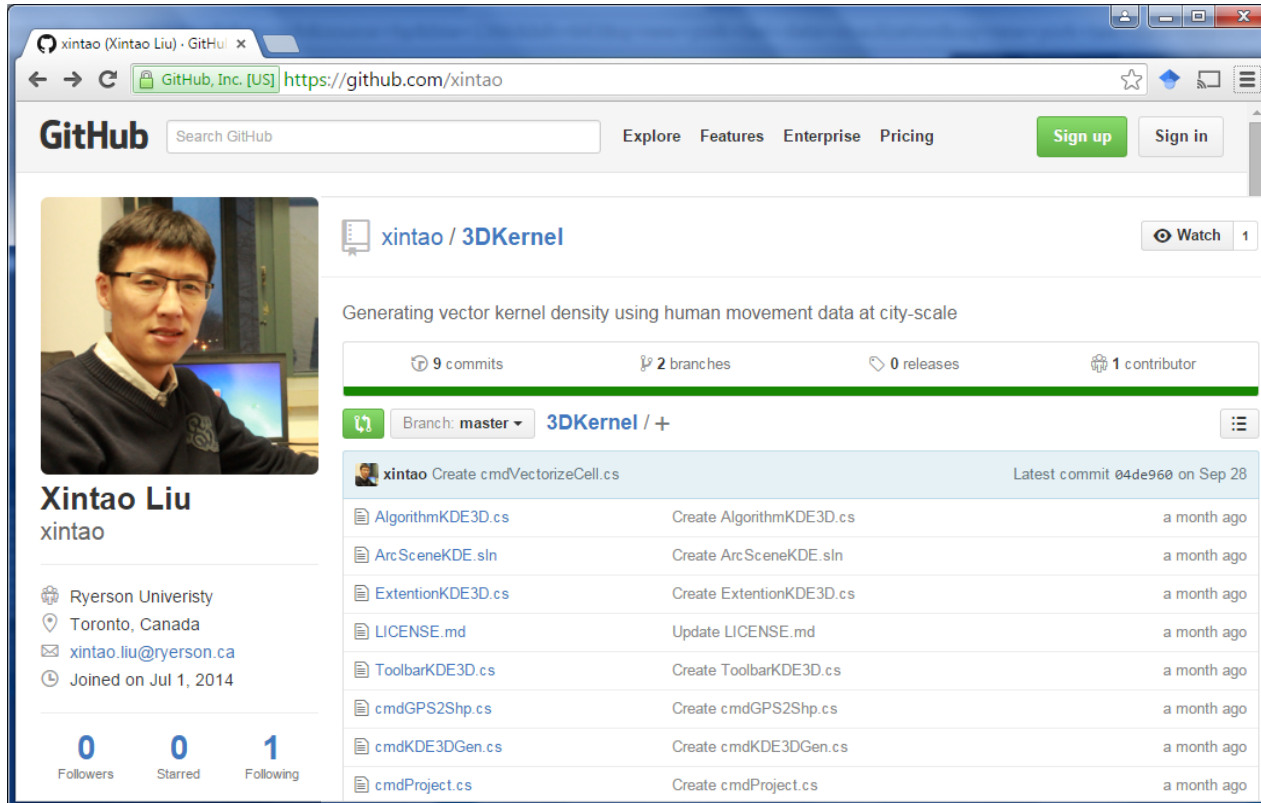
▶ Projecting travel demand onto Point of Interest (POI)

$$VKD=\sum\nolimits_{i=1}^{n}(A_{i}1\times B_{i}1+A_{i}2\times B_{i}2)$$

n is the number of cells within search radius from the current cell, $[A_{i}1\ A_{i}2]$ is the i-th Cell-POI vector, and $[B_{i}1\ B_{i}2]$ is the cell vector

Projection of vector kernel density onto Point of Interest (POI) as traffic demand

Methodology (cont.)

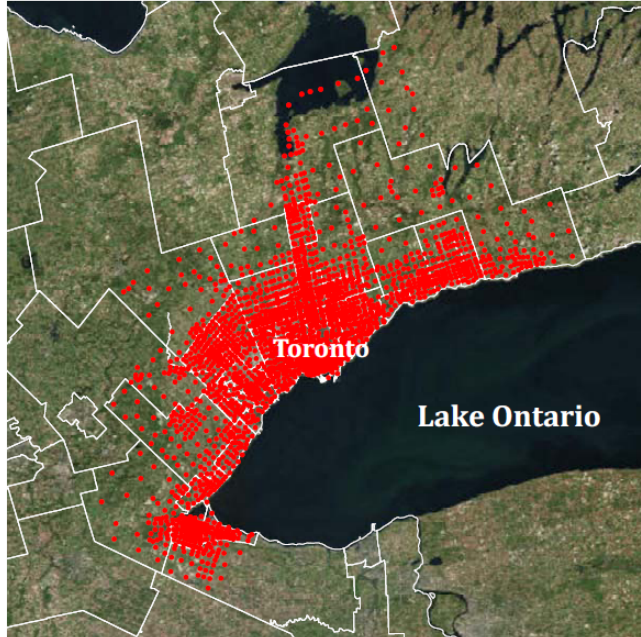▶ Open source GIS project: 3DKernel on GitHub

Study area and data: Toronto

- Transportation Tomorrow Survey data, Toronto, Canada
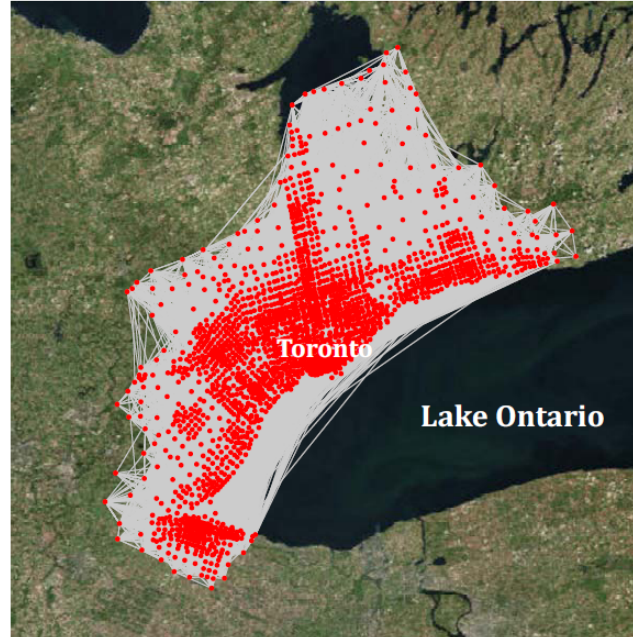
(a) 2,272 zones in Great Toronto Area in red points, and (b) 624,845 trips of 311,022 persons from 118,280 households in the year 2011.

Study area and data: Beijing

▶ Taxi GPS data in Beijing, China
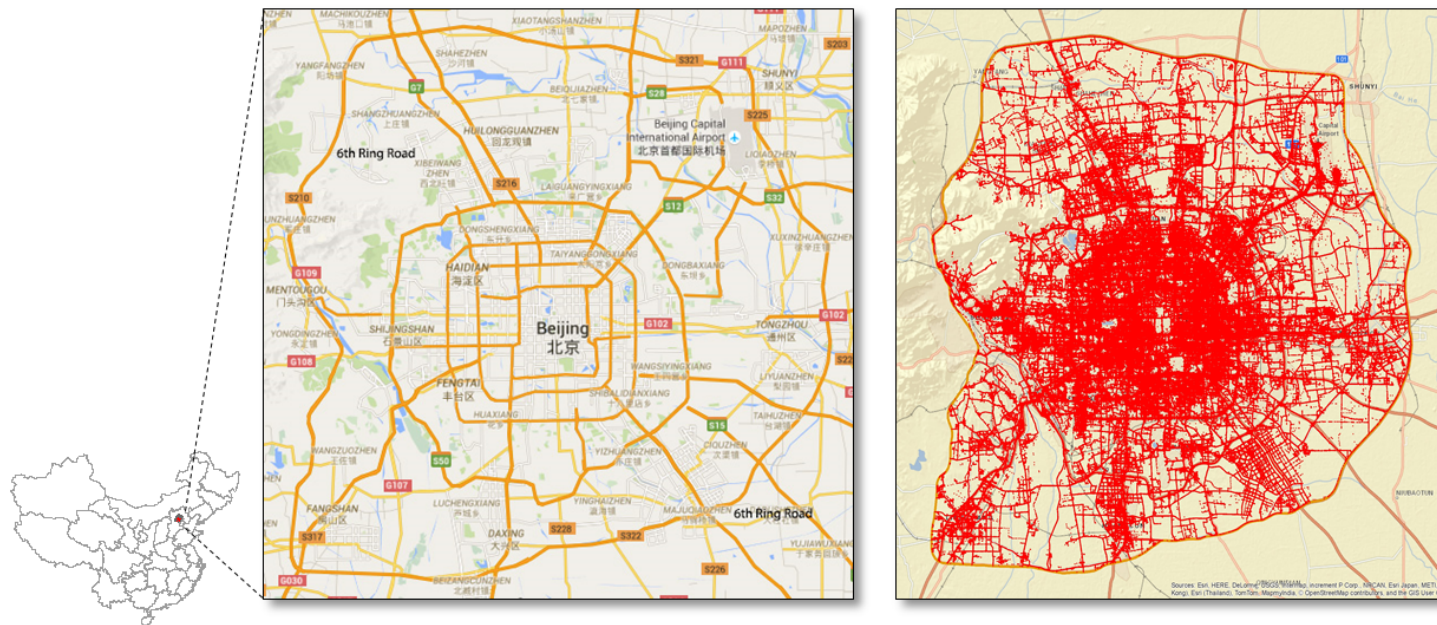
Study area: built-up area within the 6th ring road in Beijing, China (left) and total daily real-time GPS locations from 12,000 taxis (right) on Nov. 2, 2012.

Results and discussion

- This research filled previous research gap using *vector kernel density*

Liu, X., Yan, W. Y., & Chow, J. Y., 2014. Time-geographic relationships between vector fields of activity patterns and transport systems. *Journal of Transport Geography*, 42, 22-33.
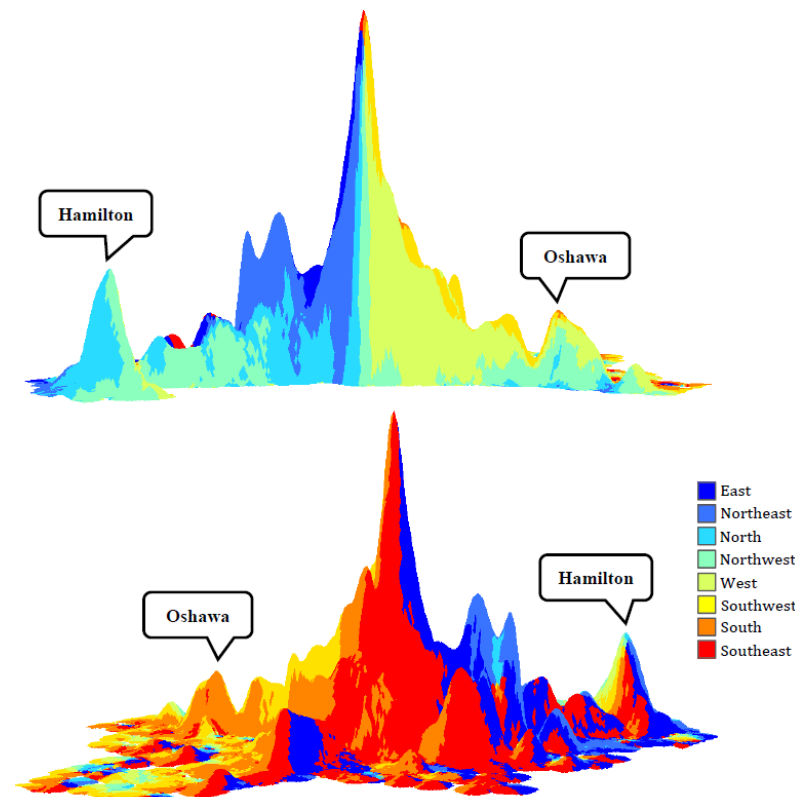
Results and discussion (cont.)

▶ Difference of densities
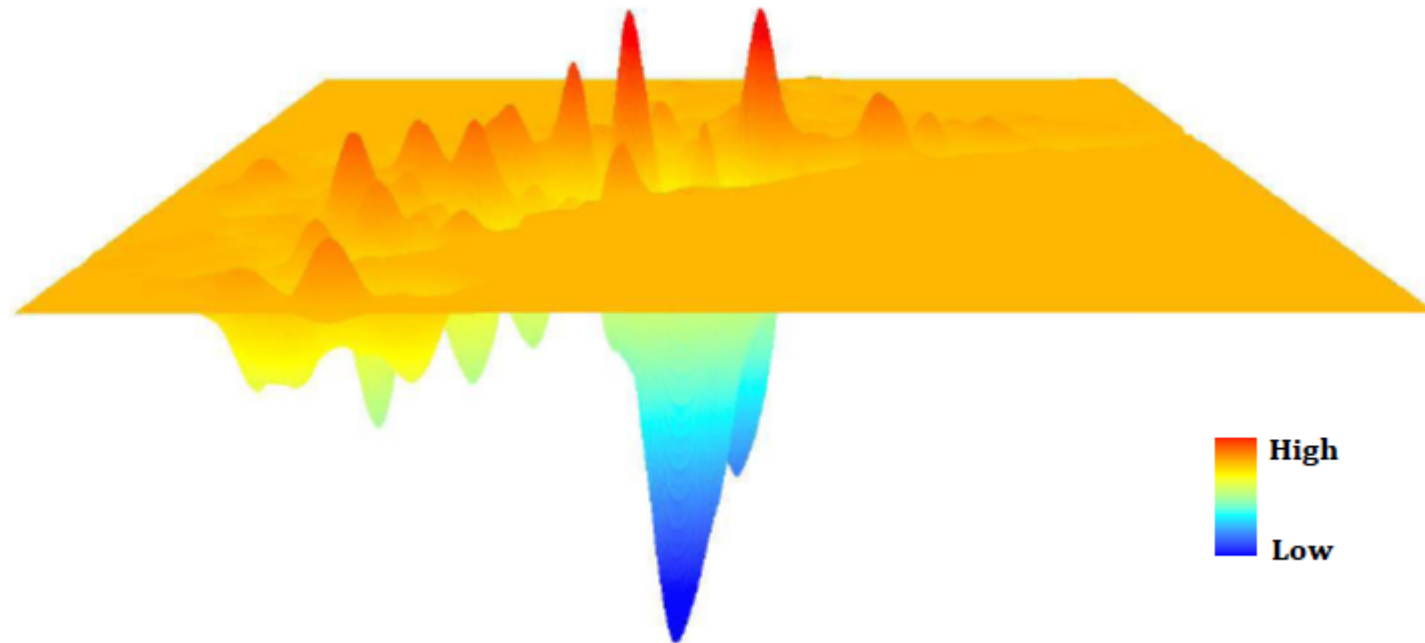
The difference of densities at 8:00 AM between the year 2006 and 2011 in GTA.
(Note: the blue arrow means the negative differences, while the red arrow means thepositive differences).

Results and discussion (cont.)

▶ Areas of density as the indicator of accessibility.

$$Coverage = \sum_{k=0}^{n} W_k D_k \qquad\qquad Rate = \frac{C_o - C_r}{C_r}$$

The transit line and stops of bus #506 in Toronto (left) and its areas of density as the indicator of accessibility.

Results and discussion (cont.)

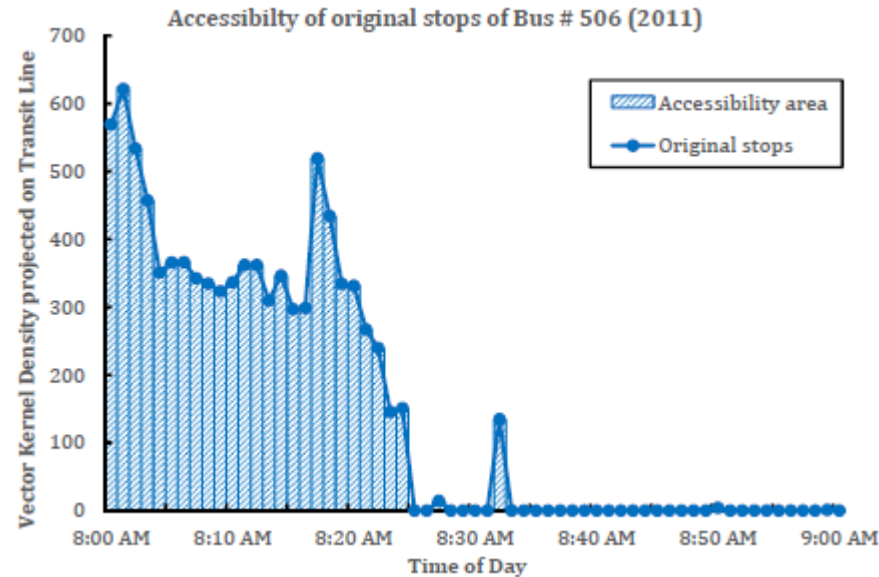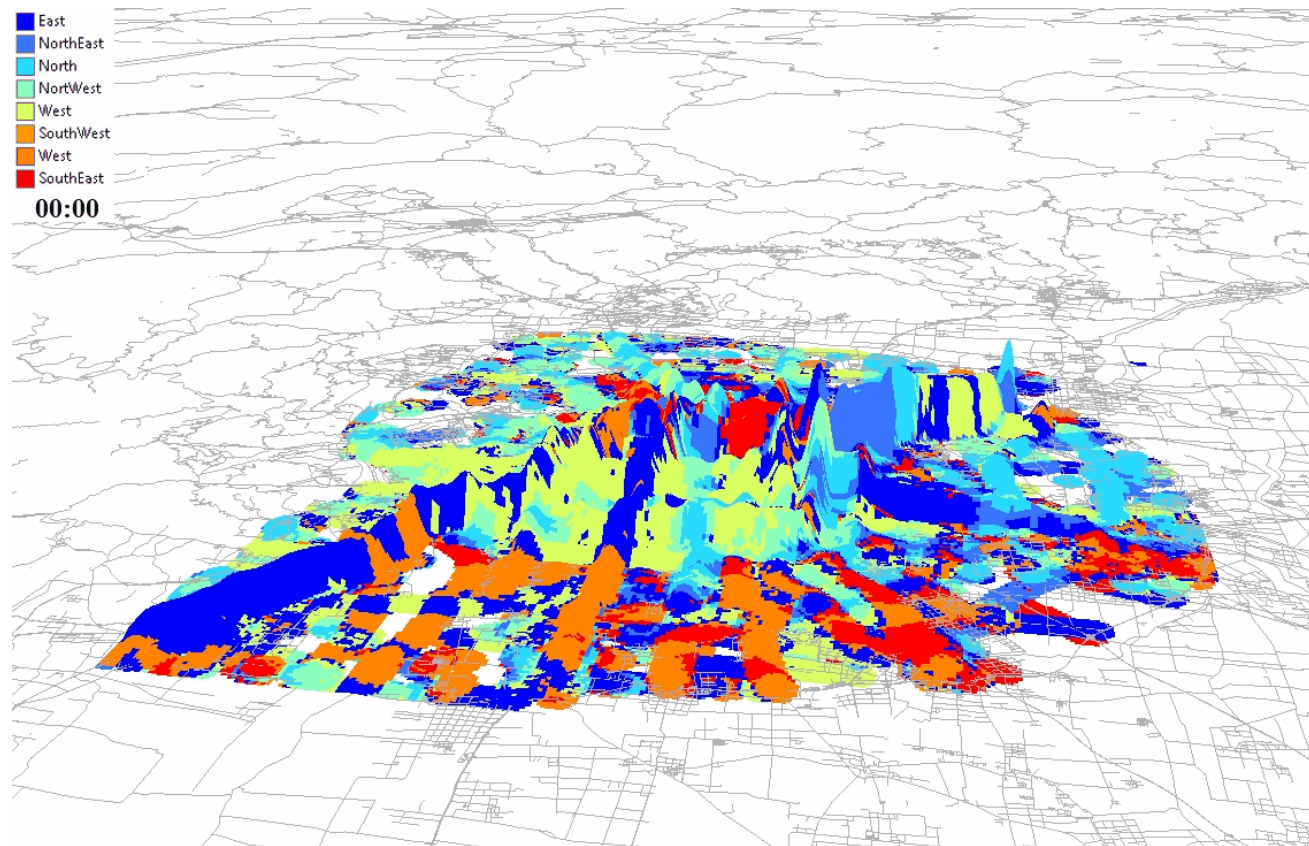▶ Visual analytic analysis

3D KD map during the day of Nov. 2, 2012 in Beijing.

Results and discussion (cont.)

▶ Visualization of impulses

Differential between
7:00 -8:00 on Friday
Nov. 2, 2012

Differential between
7:00 -8:00 on Saturday
Nov. 3, 2012

Differential between
7:00 -8:00 on Sunday
Nov. 4, 2012

Differential between
7:00 -8:00 on Monday
Nov. 5, 2012

■ East ■ NorthEast ■ North ■ NorthWest ■ West ■ SouthWest ■ South ■ SouthEast
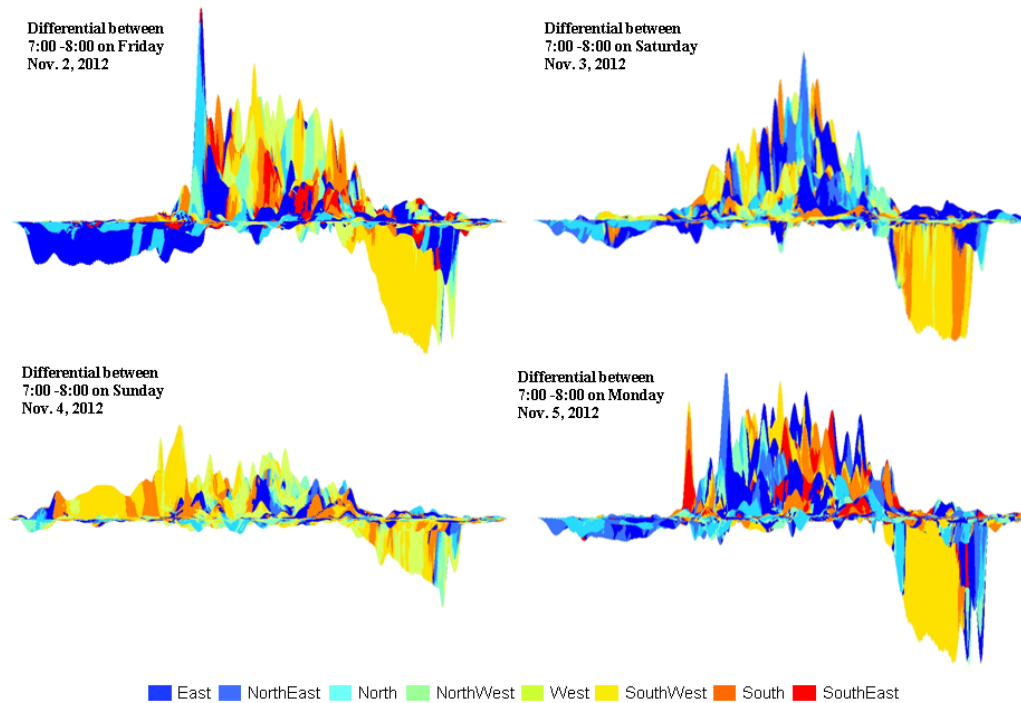
Vector kernel density differentials between 7:00 to 8:00 in four consecutive days in Nov. 2012, Beijing, China

Results and discussion (cont.)

▶ Travel demand pattern analysis

Mixed scalar projection of travel demand onto five selected POIs in Beijing

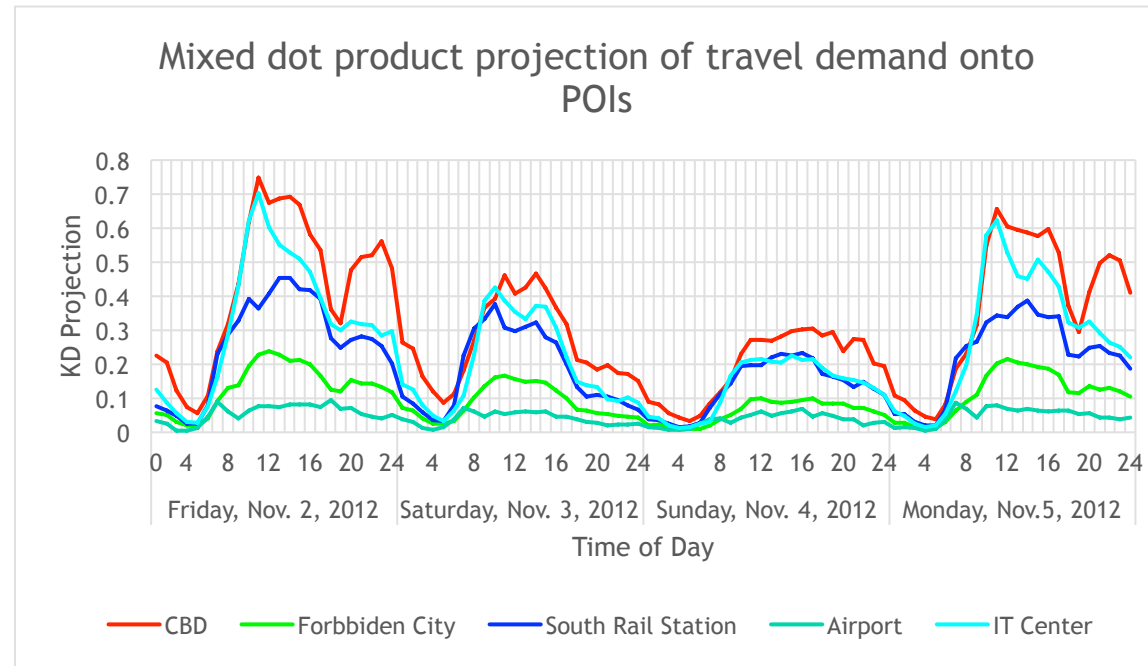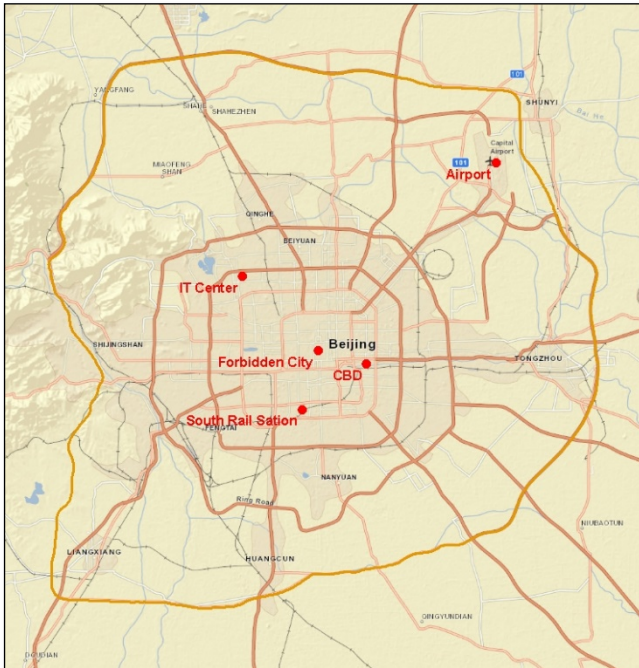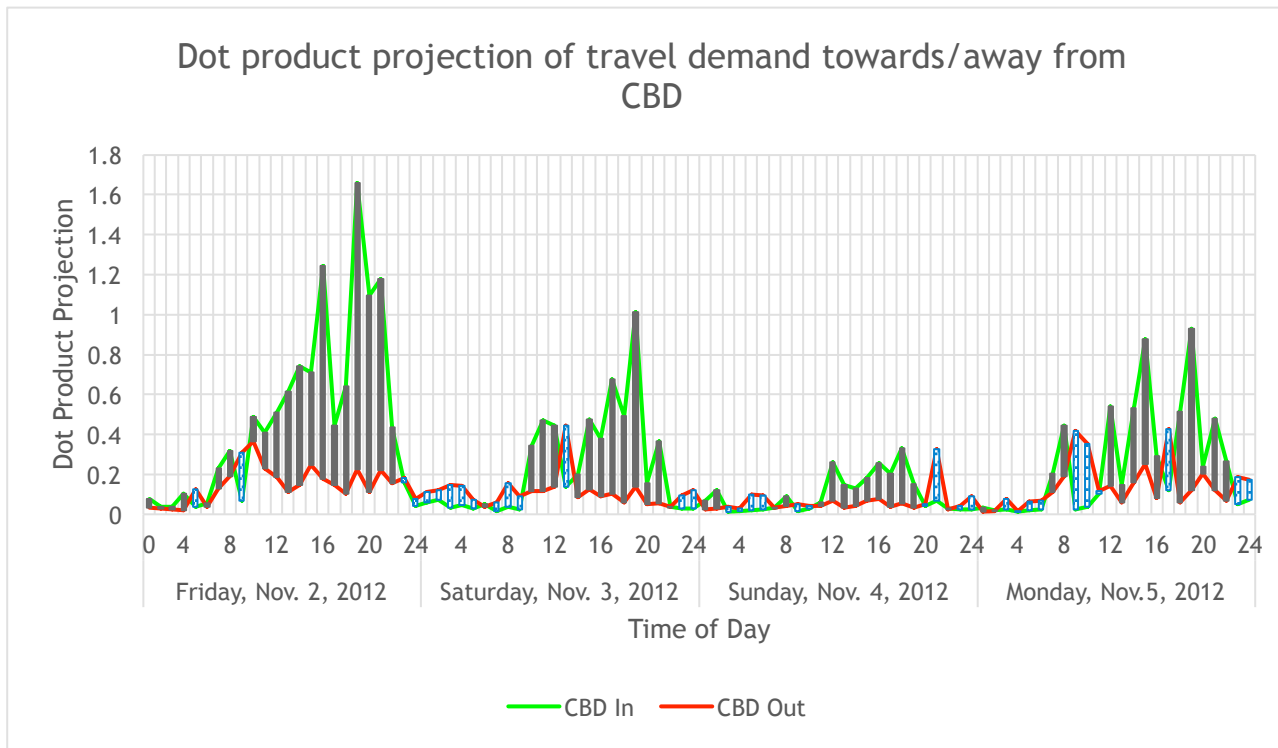# Results and discussion (cont.)

▶ Travel demand pattern analysis

Dot product projection of travel demand towards/away from CBD

$$Demand = \sum\nolimits_{t=0}^{n} W_t\, T_t$$

$$Rate = D_t t - D_t a\, /D_t a$$

Comparison and calculation of travel demand projection towards/away from POIs.

Conclusion and future work

- Conclusion

  - The results demonstrated the capability in visual analytics of travel demand using vector kernel densities from both theoretical and empirical perspectives;

  - An integrated 3D analytical GIS package is developed and shared as an open source project for further extension and validation for general purposes in related urban studies.

Conclusion and future work (cont.)

▶ Future work

- ❑ An online version with a real-time dashboard for travel impact visualization and quantification for public agencies, e.g. using taxi data from city of DOT in New York;

- ❑ More urban information (e.g. land use) to be integrated to infer semantic meanings.

Thanks for your attention!

Questions?

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