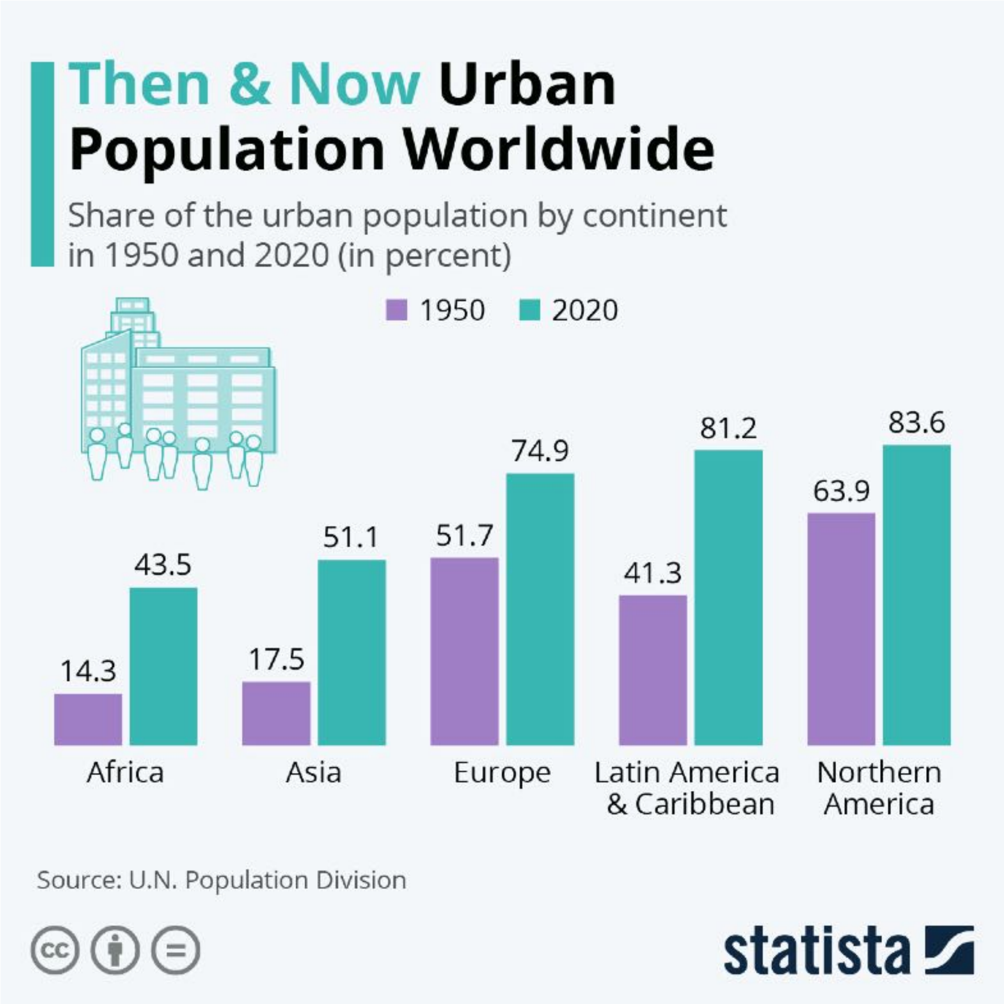
Analysing Urban Mobility Systems from Different Perspectives: a Multi-Level Schema

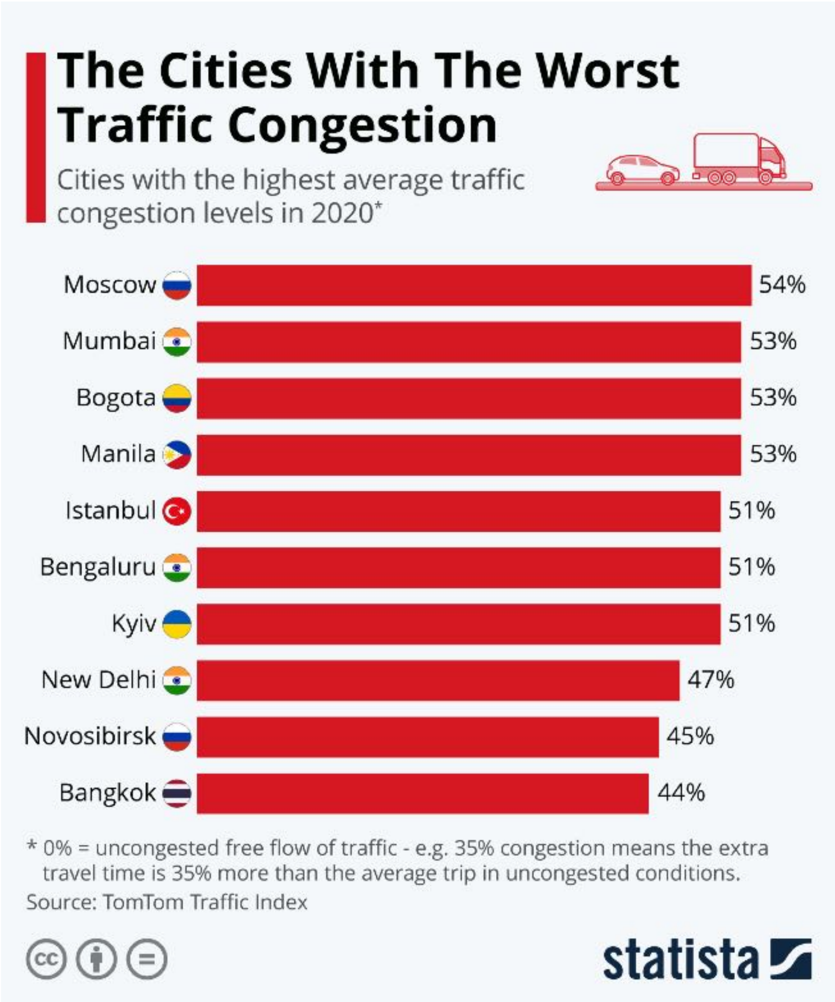
GIUSEPPE VIZZARI

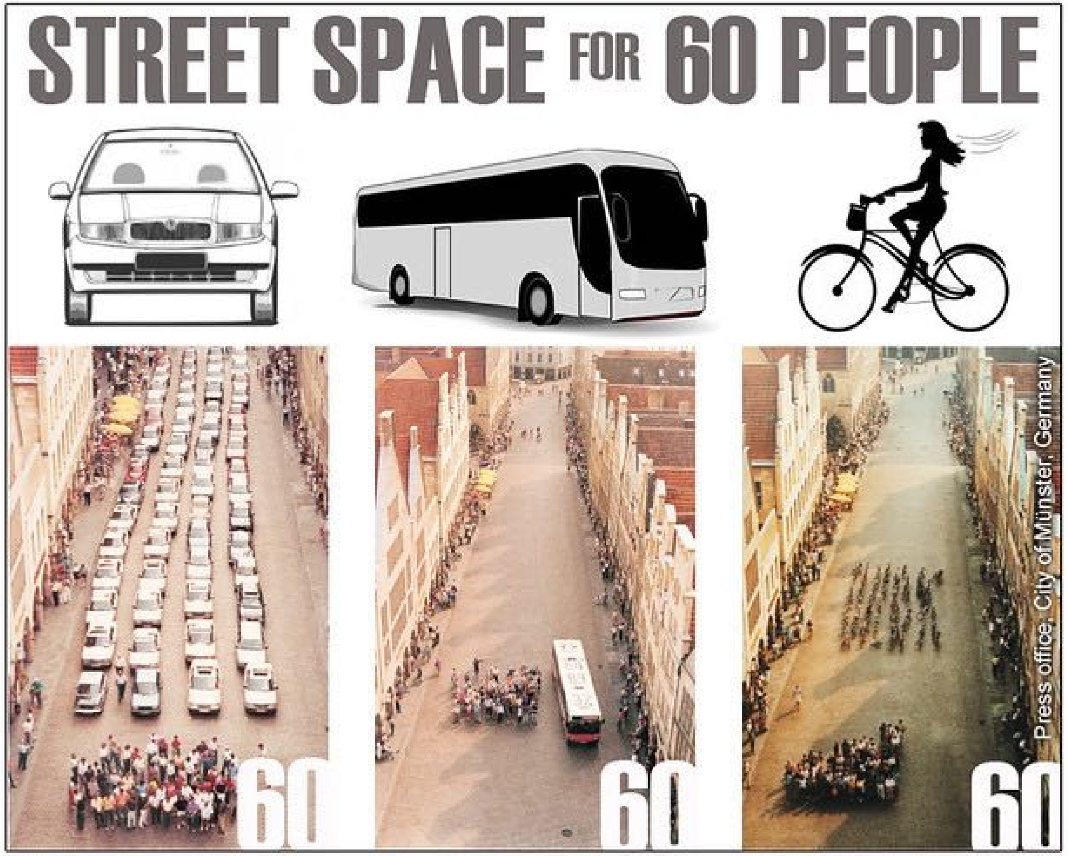
DEPARTMENT OF INFORMATICS, SYSTEMS AND COMMUNICATION
UNIVERSITY OF MILANO-BICOCCA



Urbanization worldwide

Urbanization and traffic



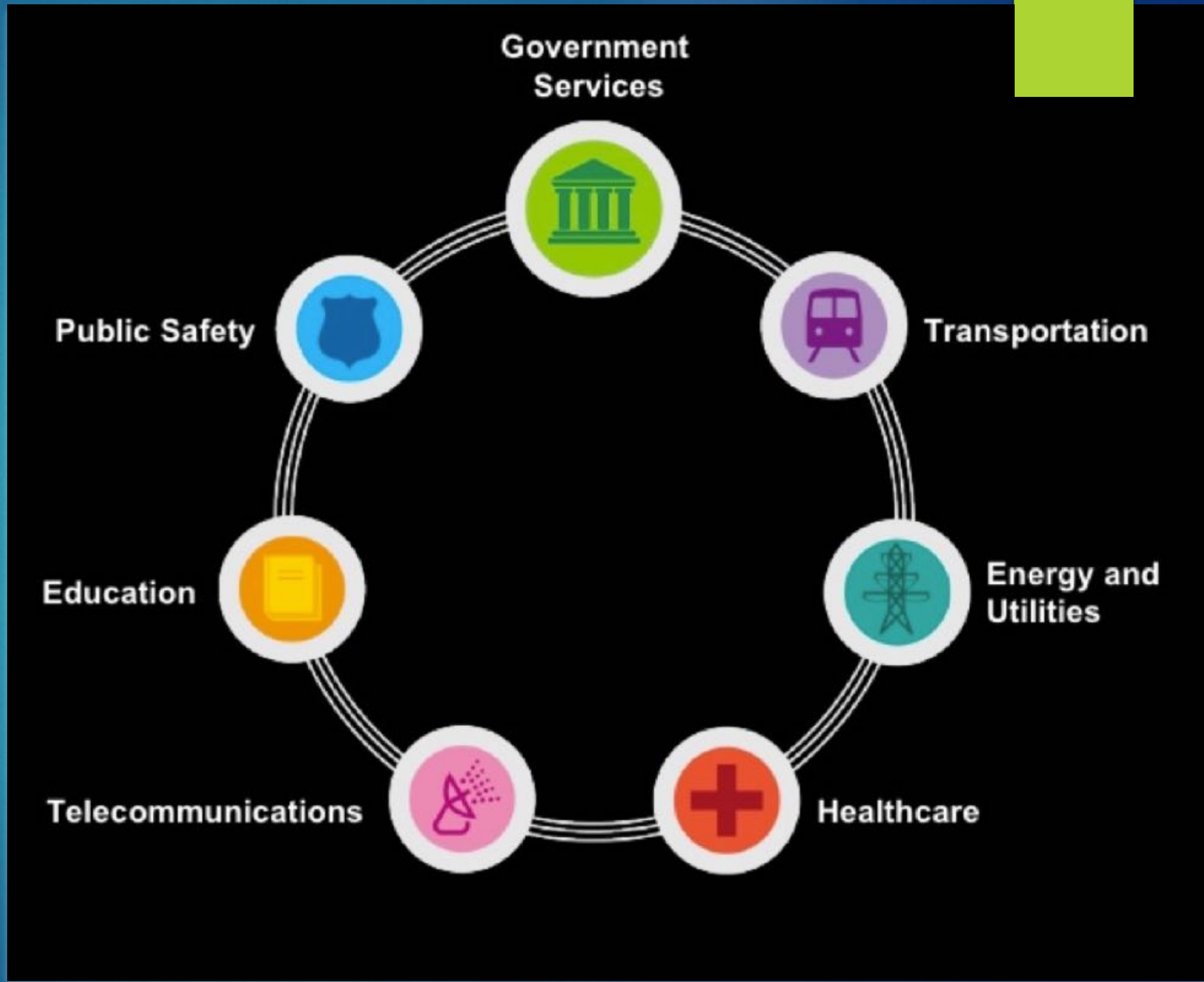


“The way we move”… and traffic implications

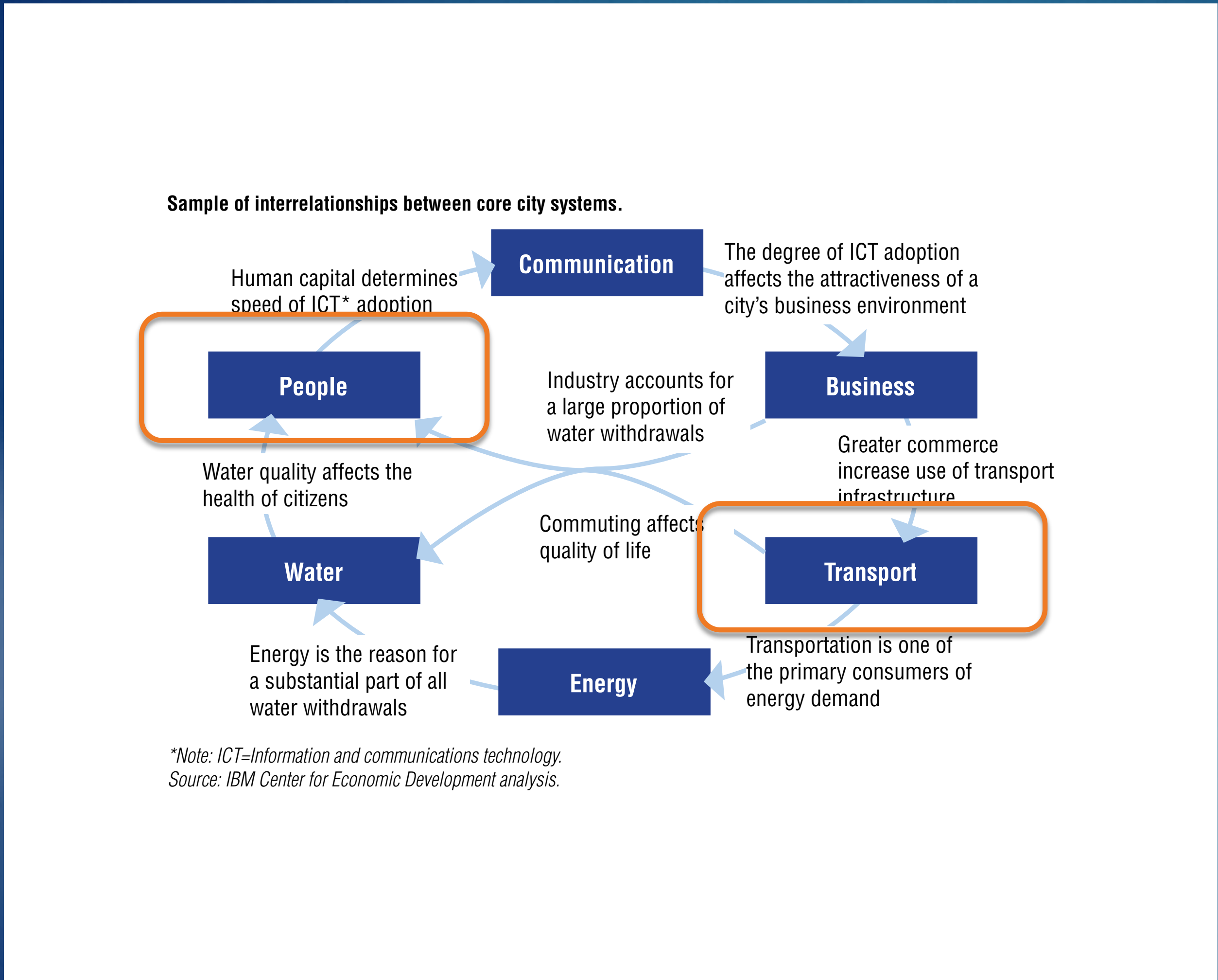
“The way we move”… and traffic implications

Smart cities to the rescue?

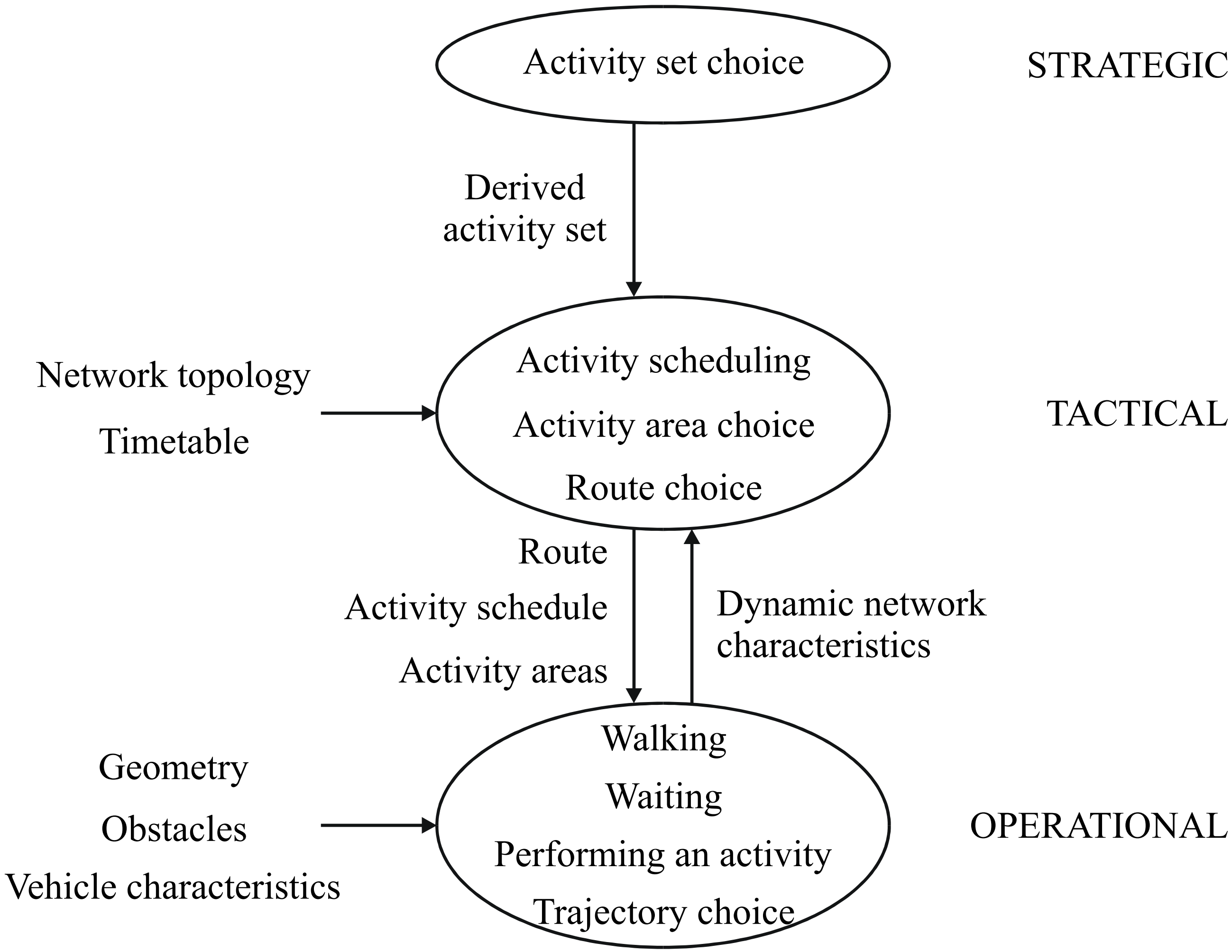
- The concept is getting a bit long in the tooth…
- But even though it was abused initially the perspective makes sense and should be pursued



Smart cities to the rescue?

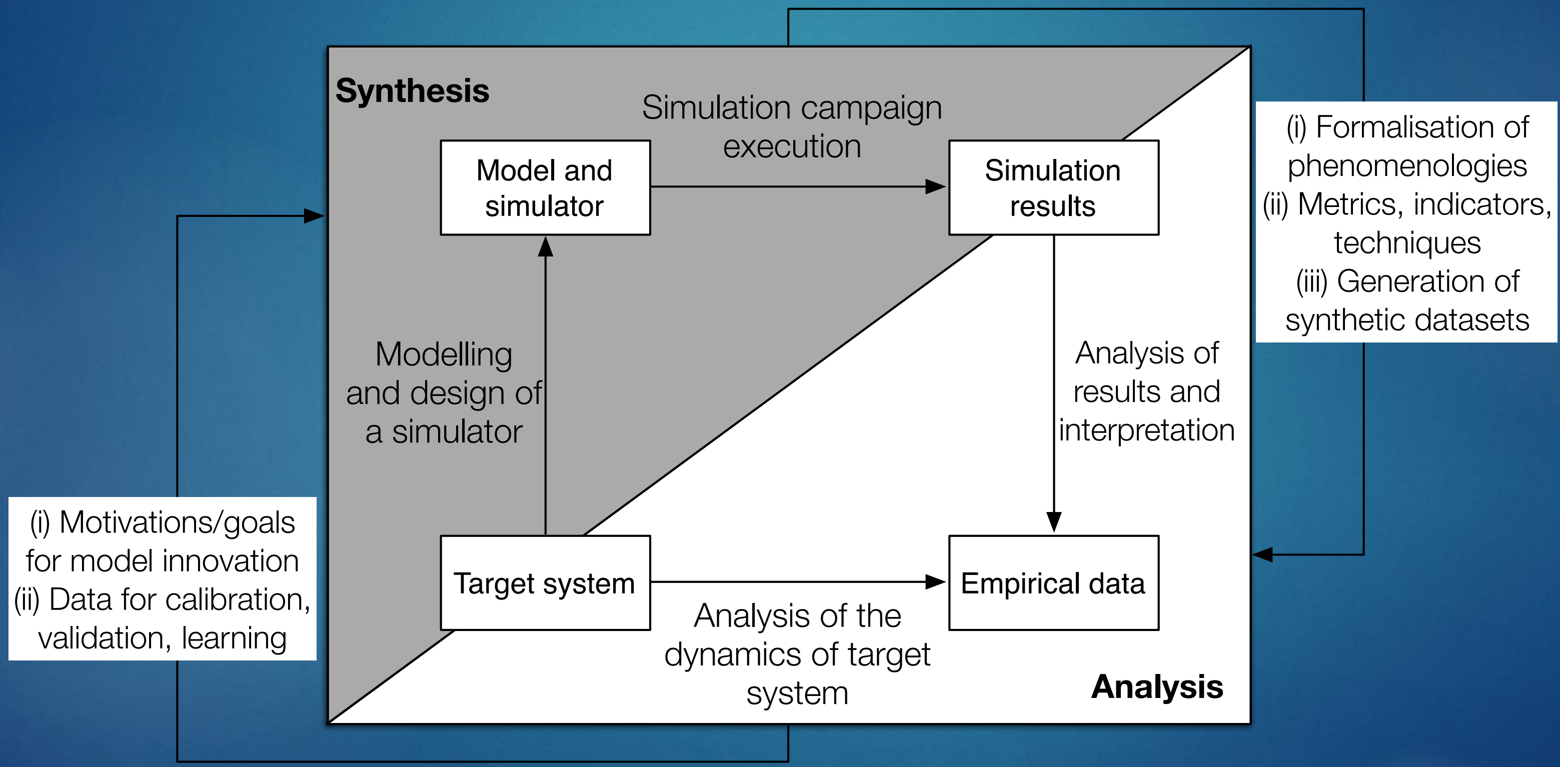


How to look at traffic systems?



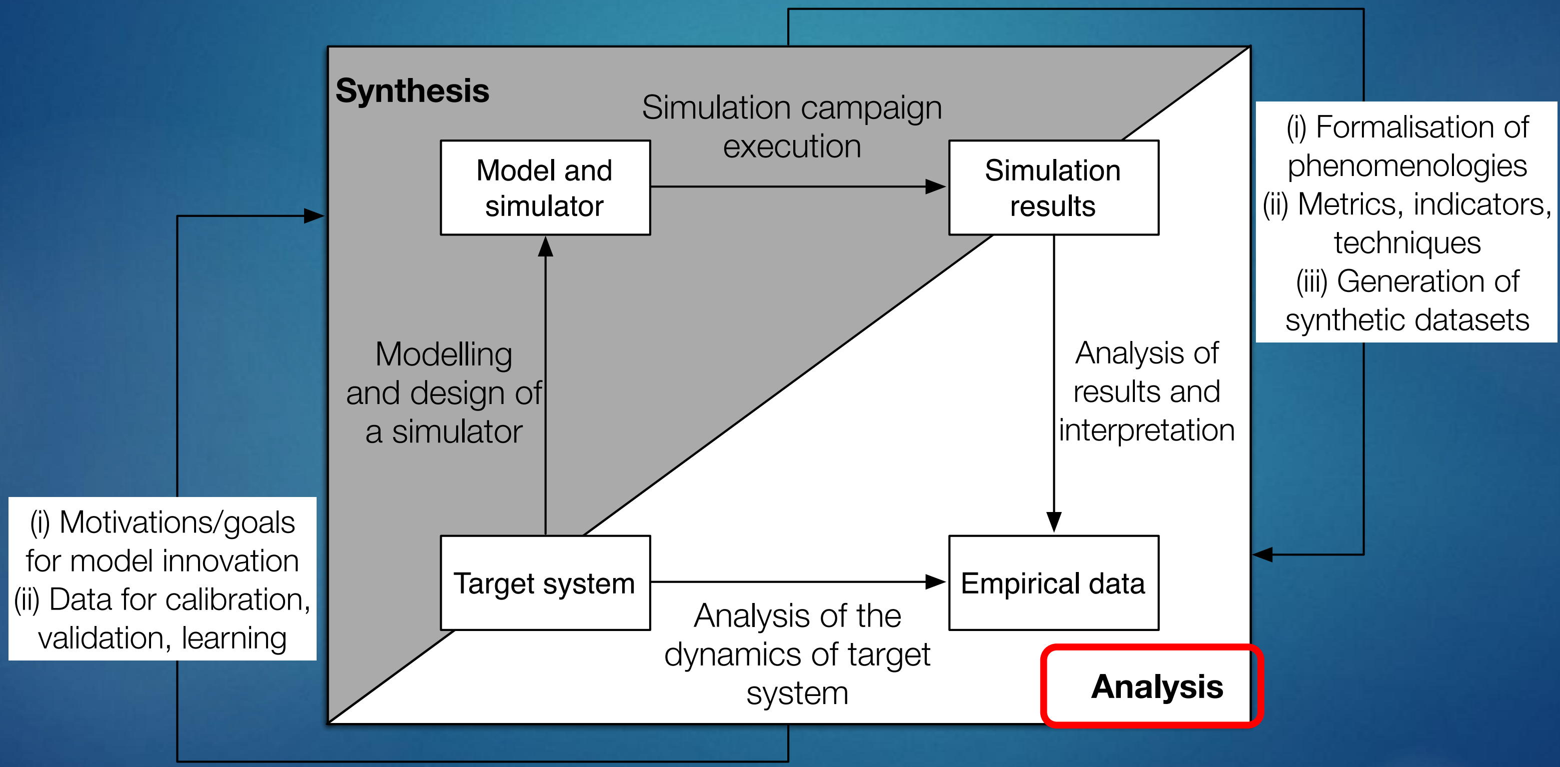
Michon, J. A. (1985). A critical view of driver behavior models: what do we know, what should we do?. *Human behavior and traffic safety*, 485-524.
Hoogendoorn, S.P., P.H.L. Bovy & W. Daamen (2001). Microscopic pedestrian wayfinding and dynamics modelling, In: M. Schreckenberg & S. Sharma, (eds.), Pedestrian and Evacuation Dynamics, Springer, Berlin, 123–154.

Studying traffic systems: analysis and synthesis

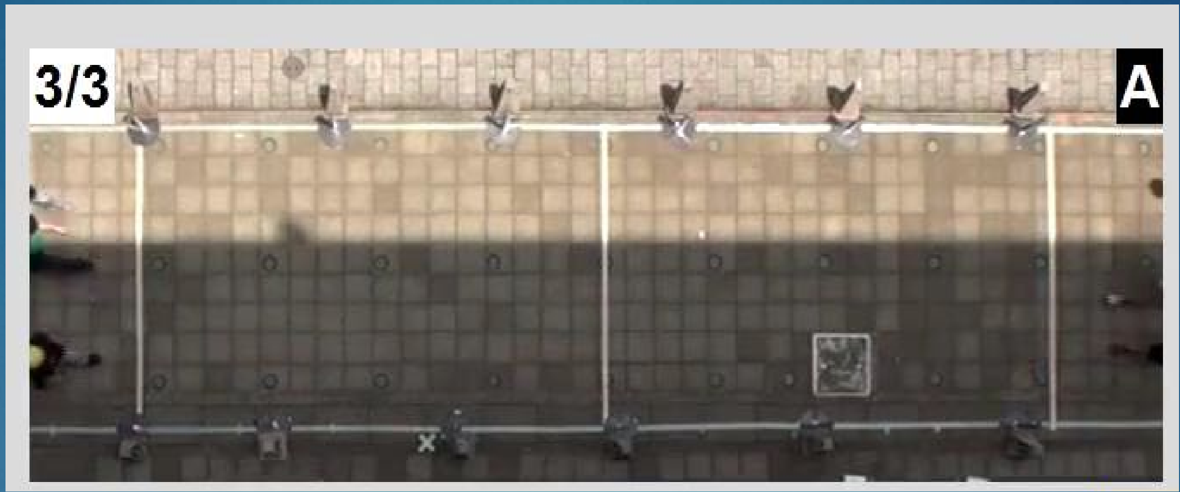


Micro scale analyses

Studying crowds: analysis and synthesis (modeling and simulation)



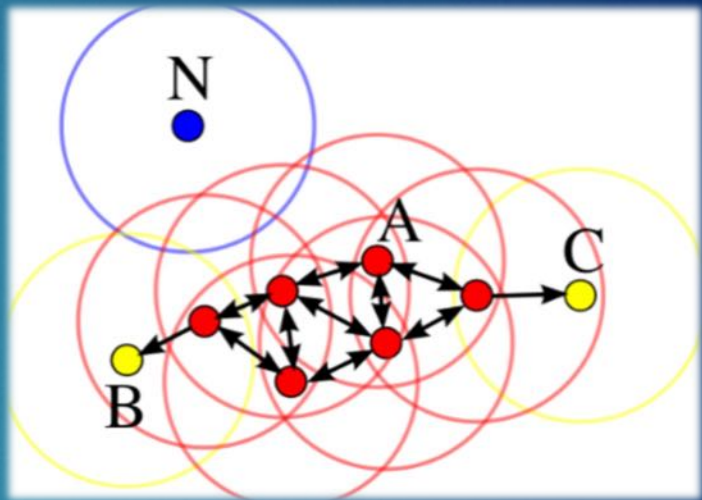
Clustering for lane identification and characterization



- Bi-directional flows are generally characterized by the formation of ***lanes***
- Few approaches proposed means of automated identification and quantitative characterization of this phenomenon
  - Order parameter [Rex & Loewen, 2007]
  - Clustering analysis [Hoogendoorn & Daamen, 2005]
  - Rotation measurement [Feliciani & Nishinari, 2016]

DBScan [Ester, Kriegel, Sander and Xu, 1996]

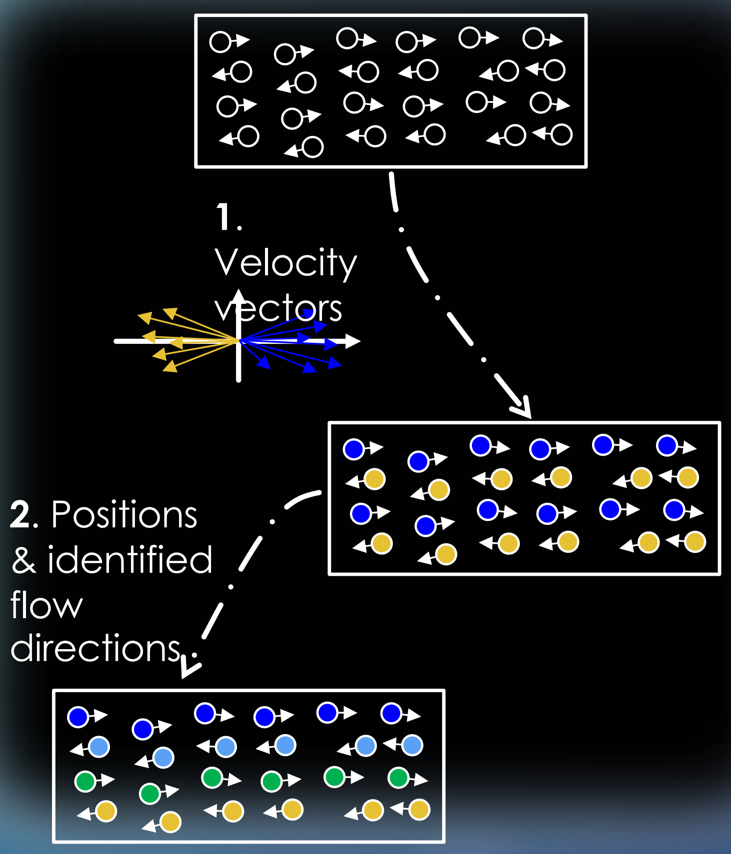
- DBSCAN (**D**ensity-**B**ased **S**patial **C**lustering of **A**pplications with **N**oise)
- Unsupervised learning algorithm based on the concept of density
- Parameters of the base version: ε, *minPoints*
- Clusters determined through the concept of neighborhood:
  - if distance between 2 points is less than ε, they are neighbors
  - when one point has at least *minPoints* neighbors it is a ***core point***
  - a cluster is defined as the set of neighboring core points, plus neighboring points (***border points***)
  - Remaining points are considered **noise**



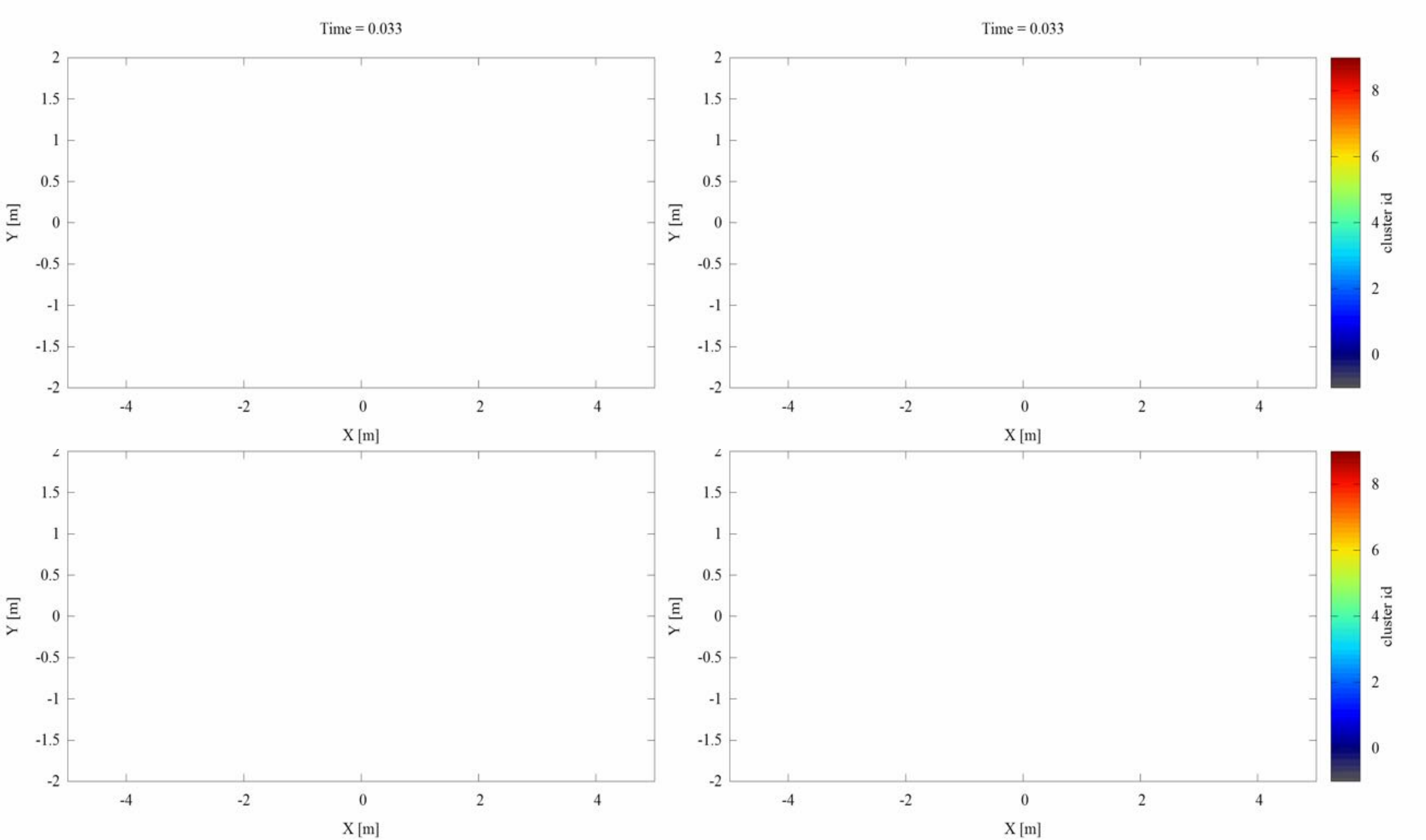
The choice of a suitable *distance metric* is crucial, just as the values for parameters

A two step DBSCAN approach

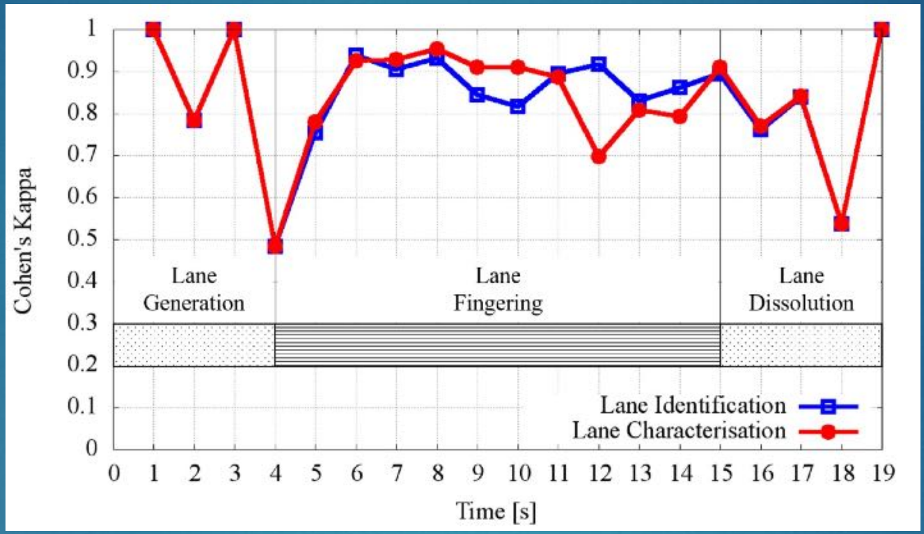
- We employed a two step clustering approach
  - The first application of DBCAN considers velocity vectors to separate main flows according to the direction
  - The second one further subdivides clusters achieved from the previous step according also to positions
- Different distance metrics, essentially evaluating in step (i) angle among velocities and in step (ii) distance among pedestrians (discounted for velocity – the preceding person can be a little more far away than person on the side)
- Overall 4 parameters (different ε and *minPoints* in the two steps)



Achieved results

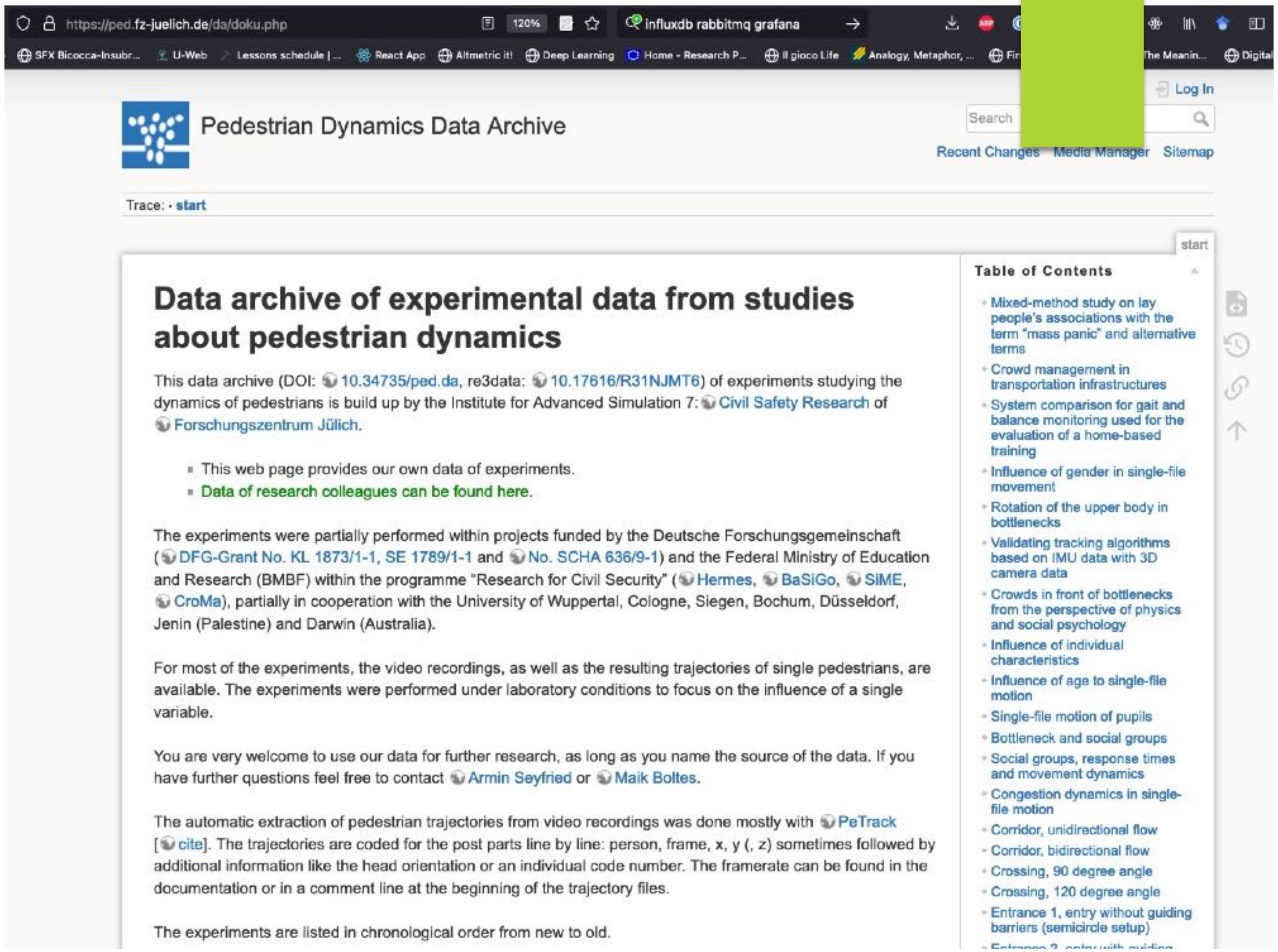


Agreement with human annotator



- Cohen’s Kappa coefficient is used to measure the level of inter-rater agreement between two coders in classifying a certain subject
- Pedestrians have been classified considering:
  - their condition of belonging or not to any lane (i.e. *gross classification – lane identification*)
  - their belonging to a certain lane (i.e. *granular classification – lane characterization*)

Where to get data to analyze?



https://ped.fz-juelich.de/da/doku.php

Log In

Pedestrian Dynamics Data Archive

Search

Recent Changes Media Manager Sitemap

Trace: · start

start

Data archive of experimental data from studies about pedestrian dynamics

This data archive (DOI: 10.34735/ped.da, re3data: 10.17616/R31NJMT6) of experiments studying the dynamics of pedestrians is build up by the Institute for Advanced Simulation 7: Civil Safety Research of Forschungszentrum Jülich.

- This web page provides our own data of experiments.
- Data of research colleagues can be found here.

The experiments were partially performed within projects funded by the Deutsche Forschungsgemeinschaft (DFG-Grant No. KL 1873/1-1, SE 1789/1-1 and No. SCHA 636/9-1) and the Federal Ministry of Education and Research (BMBF) within the programme "Research for Civil Security" (Hermes, BaSiGo, SIME, CroMa), partially in cooperation with the University of Wuppertal, Cologne, Siegen, Bochum, Düsseldorf, Jenin (Palestine) and Darwin (Australia).

For most of the experiments, the video recordings, as well as the resulting trajectories of single pedestrians, are available. The experiments were performed under laboratory conditions to focus on the influence of a single variable.

You are very welcome to use our data for further research, as long as you name the source of the data. If you have further questions feel free to contact Armin Seyfried or Maik Boltes.

The automatic extraction of pedestrian trajectories from video recordings was done mostly with PeTrack [cite]. The trajectories are coded for the post parts line by line: person, frame, x, y (, z) sometimes followed by additional information like the head orientation or an individual code number. The framerate can be found in the documentation or in a comment line at the beginning of the trajectory files.

The experiments are listed in chronological order from new to old.

Table of Contents

Urban scale analyses

From micro to urban scale

"Urban informatics is the study, design, and practice of urban experiences across different urban contexts that are created by new opportunities of real-time, ubiquitous technology and the augmentation that mediates the physical and digital layers of people networks and urban infrastructures."

Foth, Choi, Satchell (2011). Urban informatics.

"The use of information and communications technology to better understand metropolitan needs, challenges, and opportunities."

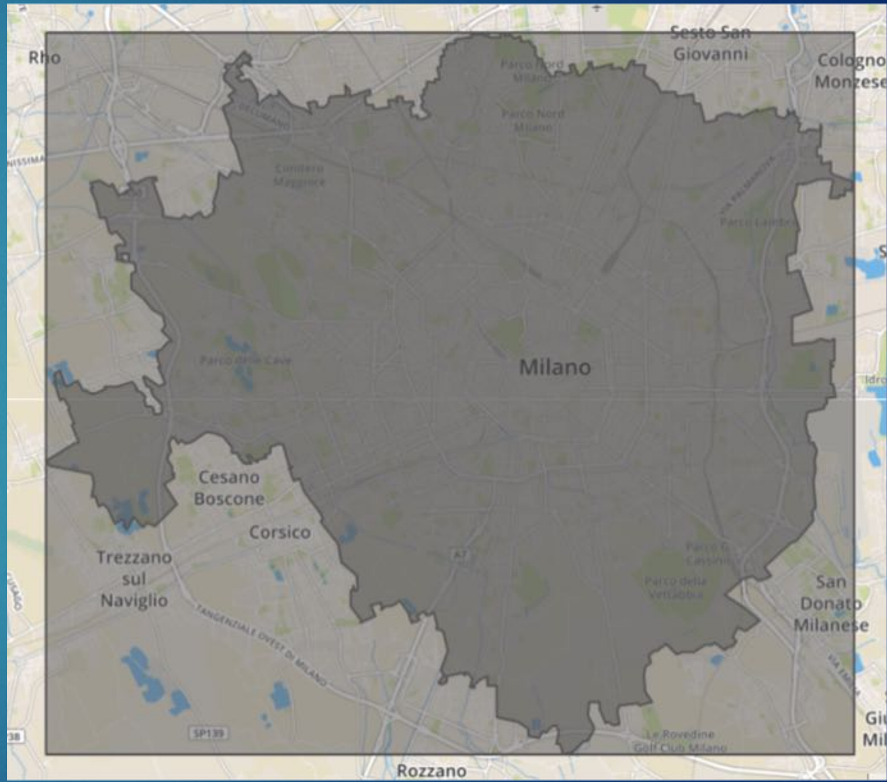
McKinsey on Society (2012). Emerging Trends in Urban Informatics.

"Urban informatics uses data to better understand how cities work. This understanding can remedy a wide range of issues affecting the everyday lives of citizens and the long-term health and efficiency of cities — from morning commutes to emergency preparedness to air quality."

Center for Urban Science and Progress (2013). What is Urban Informatics?

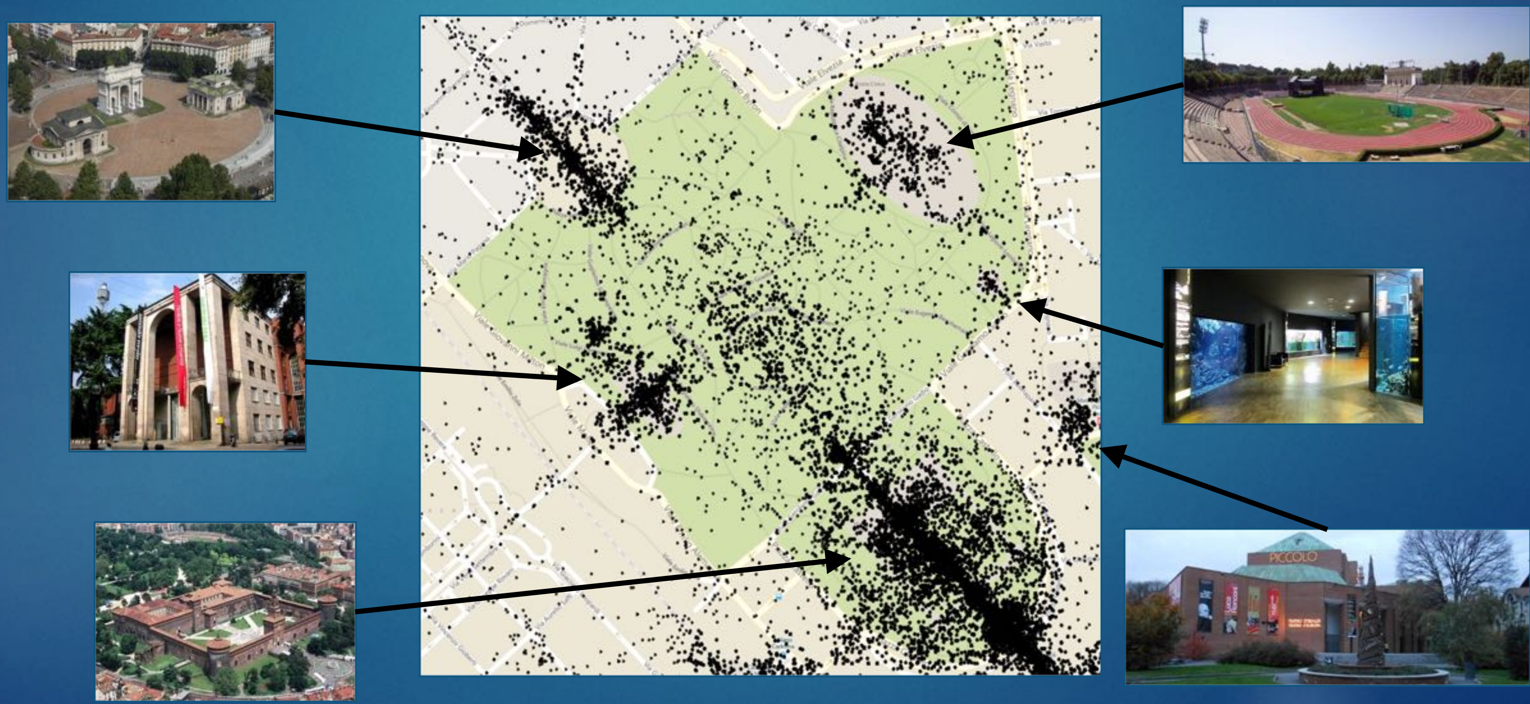
Enabling data and technologies

- Sources:
  - Flickr
  - Foursquare
- Crawling process within the city of Milano:
  - ≈ 450 000 Flickr photos
    - metadata: e.g. geo coordinates, tags, takenDate
    - 4 067 314 total photo tags
  - ≈ 50 000 Foursquare points of interest
    - metadata: e.g. geo coordinates, categories
    - 56 406 total POI categories
- QGIS (Quantum GIS)



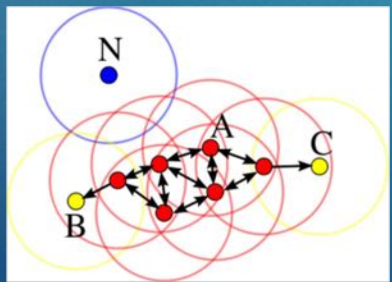
Identification of the entities within the city

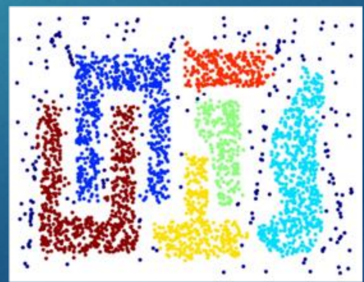
Basic idea: a *potentially interesting entity* within the city should generate a significant activity related to the associated area in the considered social media (i.e. Flickr and Foursquare).



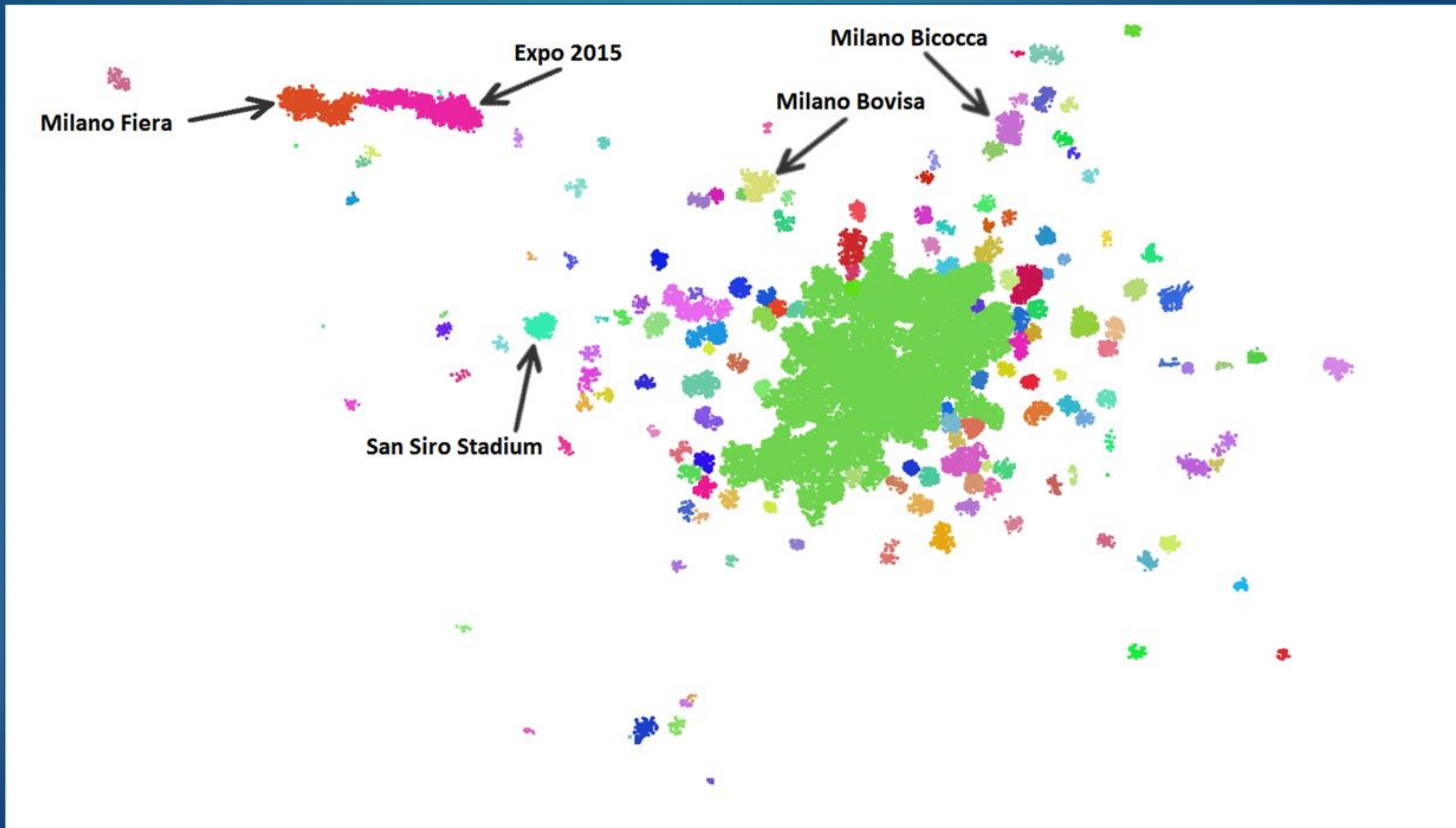
Identification of the entities: clustering

- Clustering is the process of identifying natural groupings (i.e. clusters) within multidimensional data based on some similarity measure.
- Density-based clustering algorithm: it allows to search for regions of high density (i.e. *city areas where there are many photos or POIs*) that are separated by regions of lower density (i.e. *city areas where there are few/none photos or POIs*).
- DBSCAN satisfies our requirements:
  - unknown number of clusters to identify → not required
  - good efficiency on large databases → O(n log n)
  - discovery of clusters with arbitrary shape

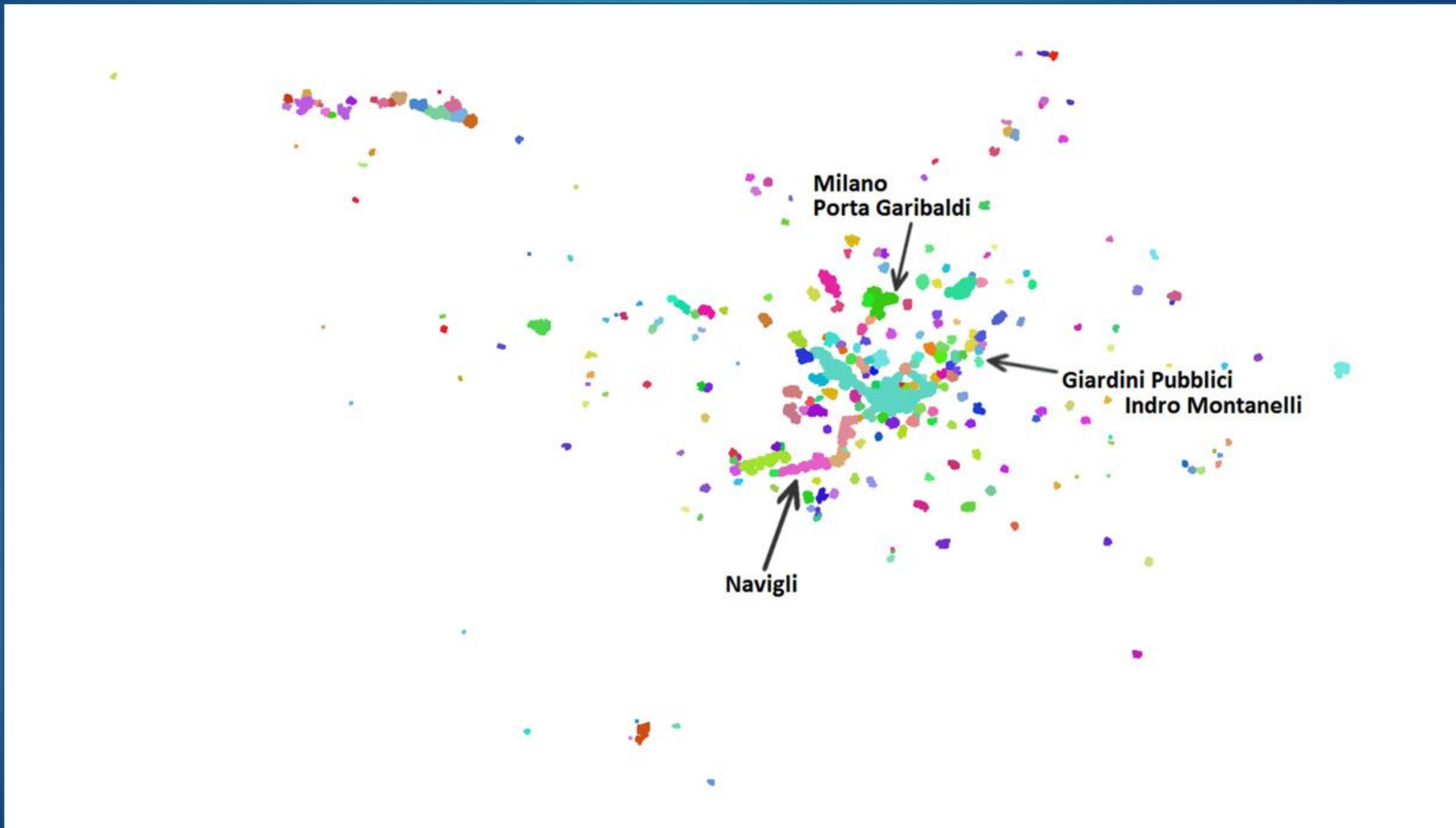




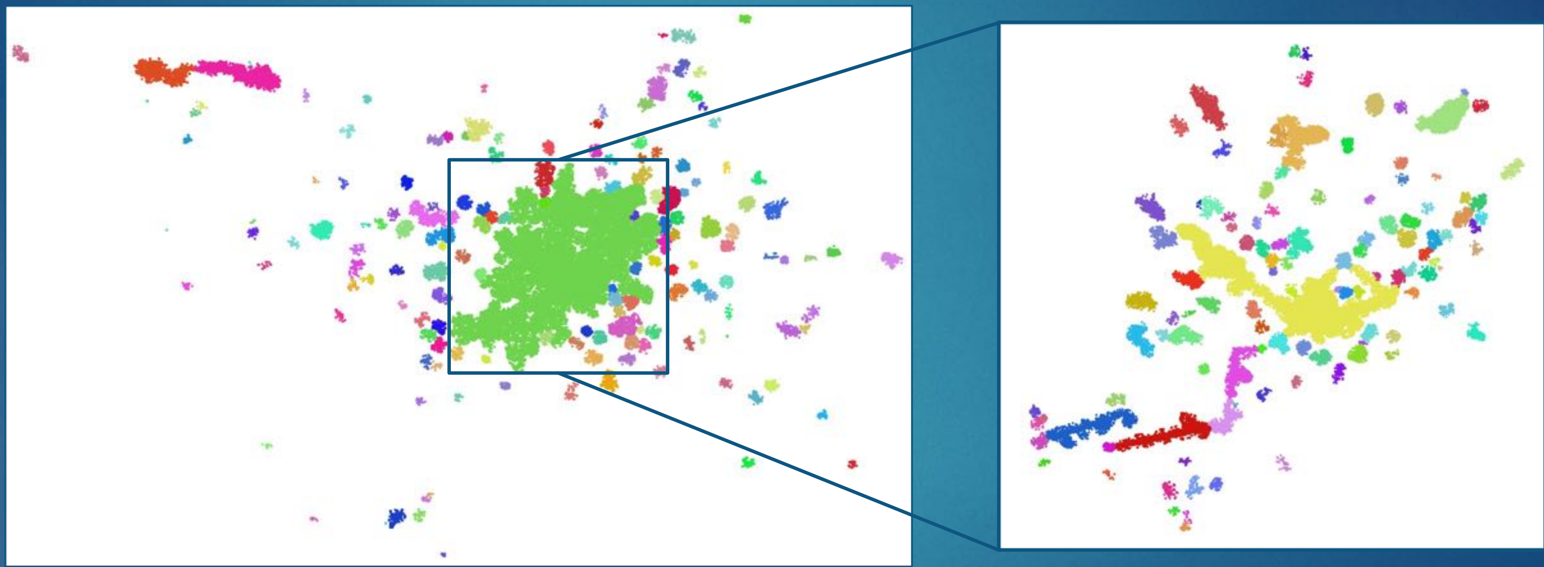
Identification of the entities: which parameters?



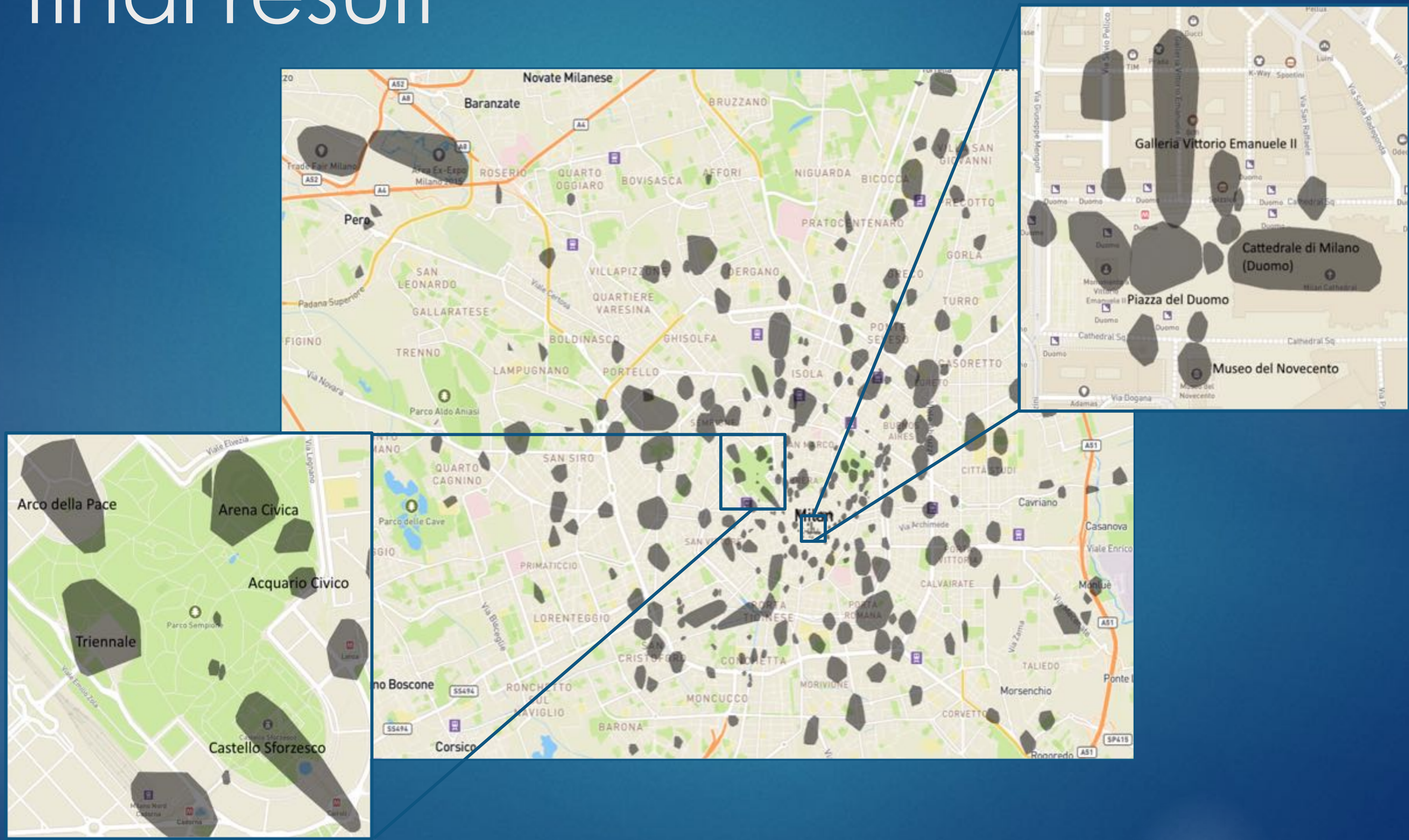
Identification of the entities: which parameters?



Identification of the entities: iterative approach



Identification of the entities: final result



Identification of the entities: quantitative evaluation

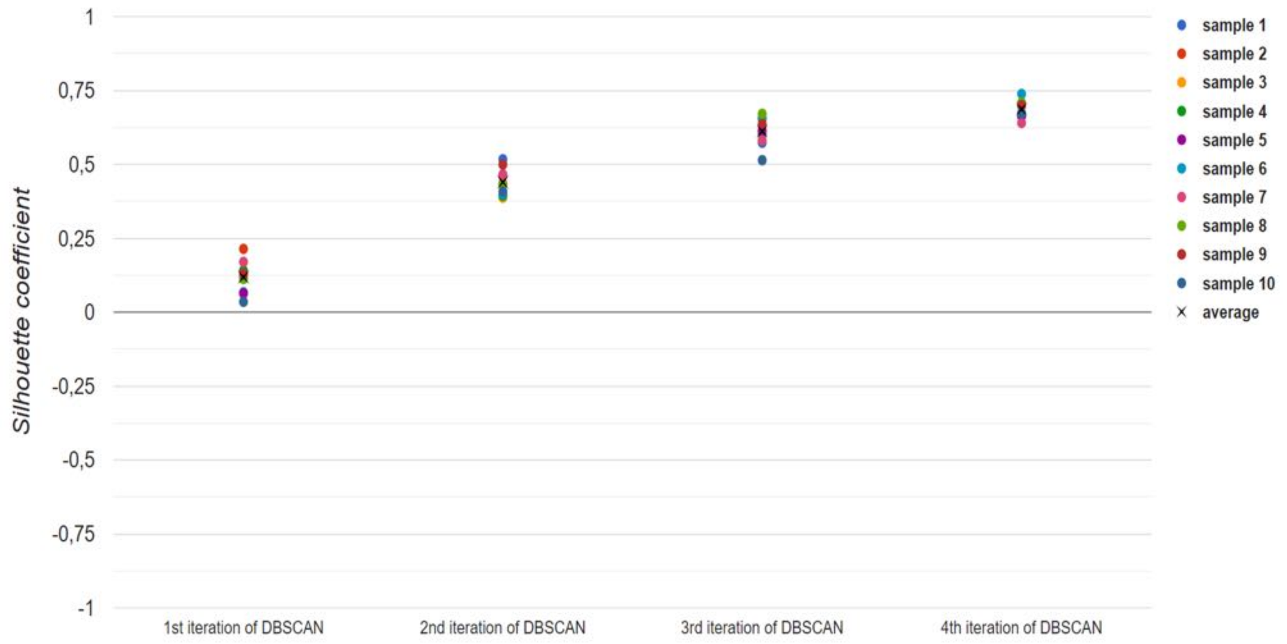
Silhouette Coefficient: internal index that reflects both the *compactness* and the *separation* of clusters.

Formally, considering an object o ∊ Ci where 1 ≤ i ≤ k and k is the number of clusters:

$$a(o) = \frac{\sum_{o' \in C_i, o \neq o'} dist(o, o')}{|C_i| - 1}$$

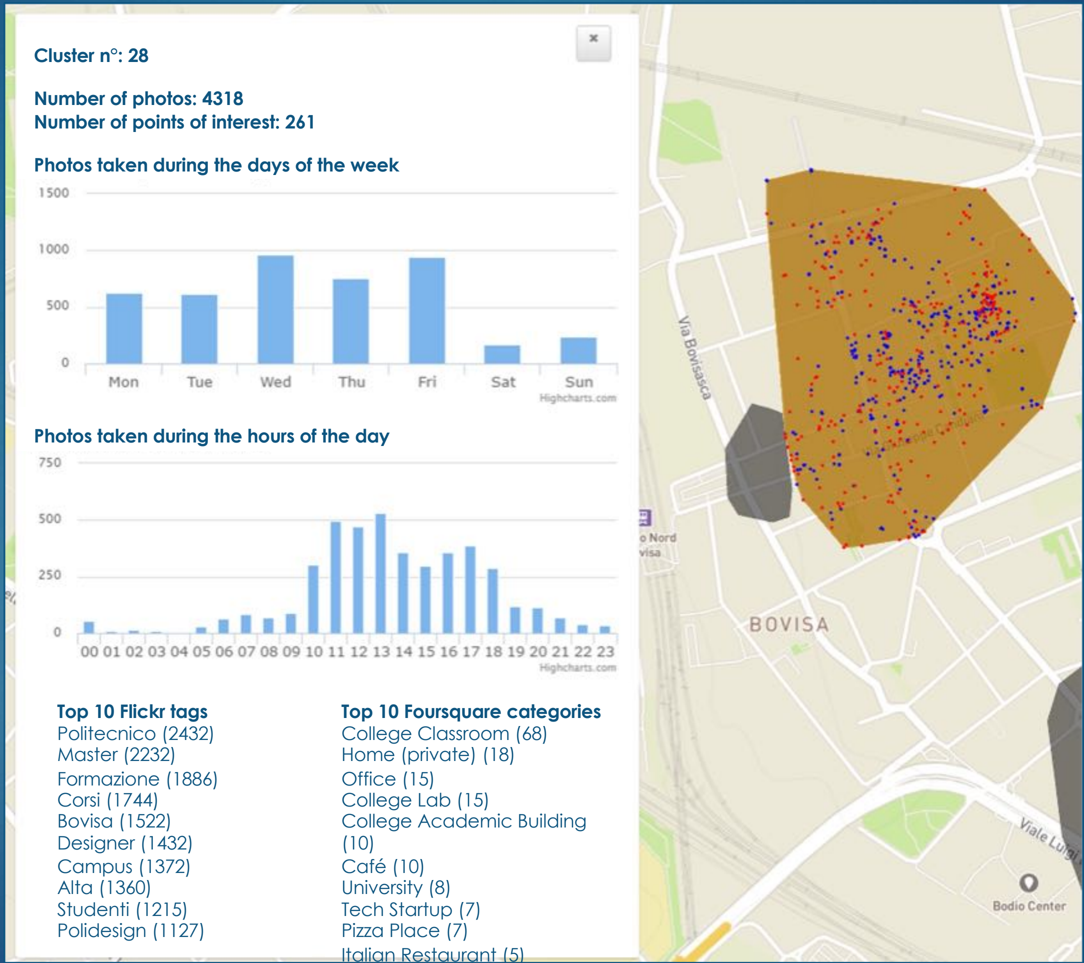
$$b(o) = \min_{C_j : 1 \leq j \leq k, j \neq i} \left\{ \frac{\sum_{o' \in C_j} dist(o, o')}{|C_j|} \right\}$$

$$s(o) = \frac{b(o) - a(o)}{\max\{a(o), b(o)\}}$$



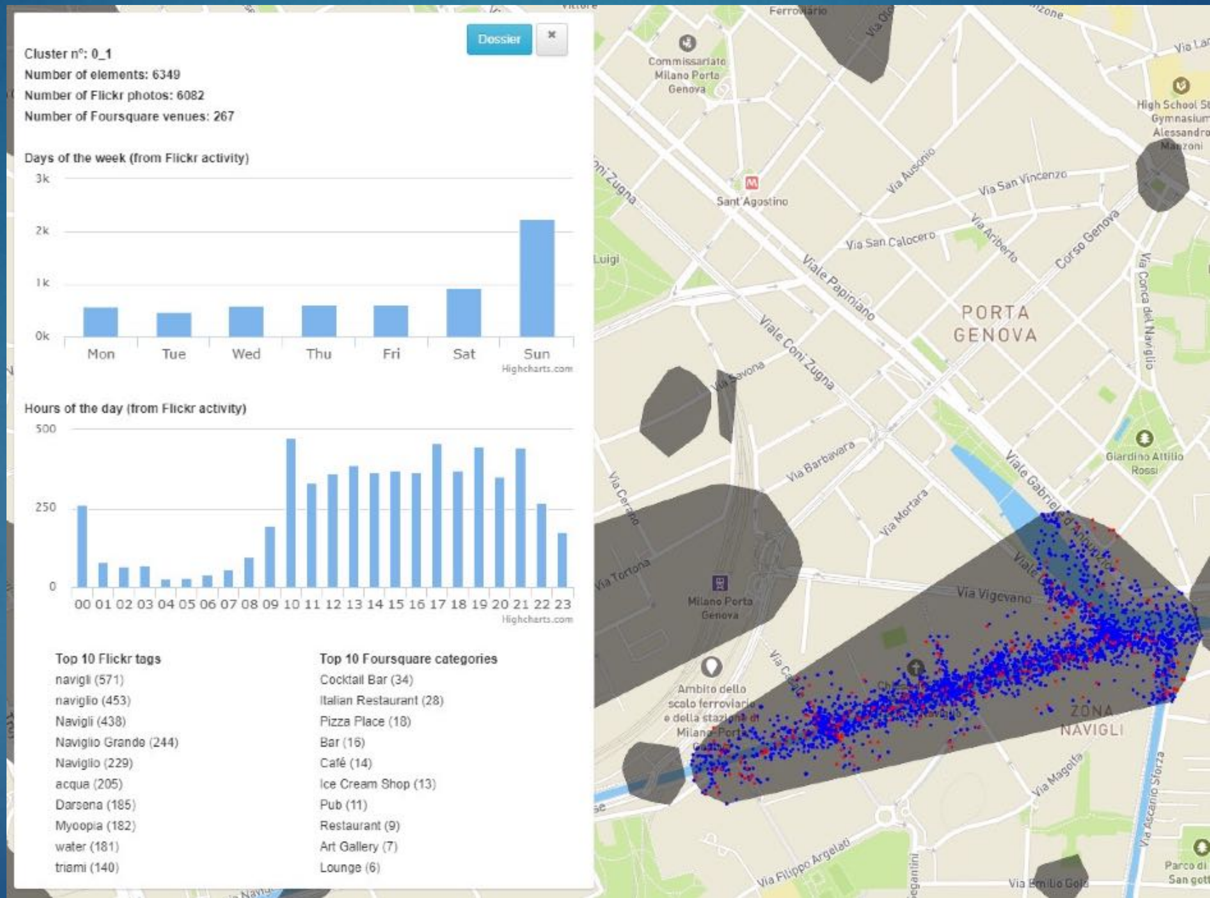
Each sample set contains 5 000 randomly selected elements (about 1% of the dataset)

Characterization of the identified entities



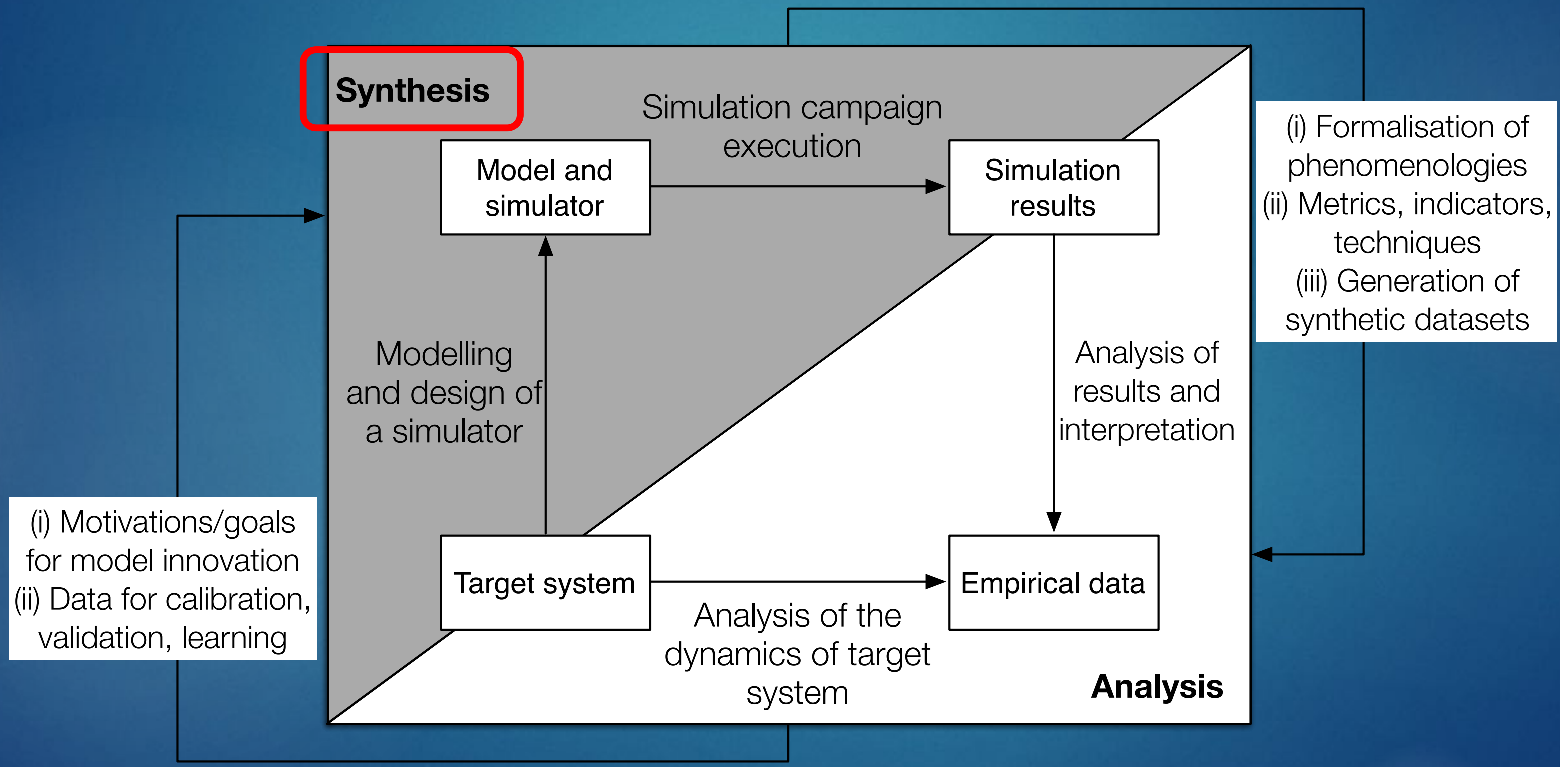
Politecnico di Milano Bovisa

Characterization of the identified entities

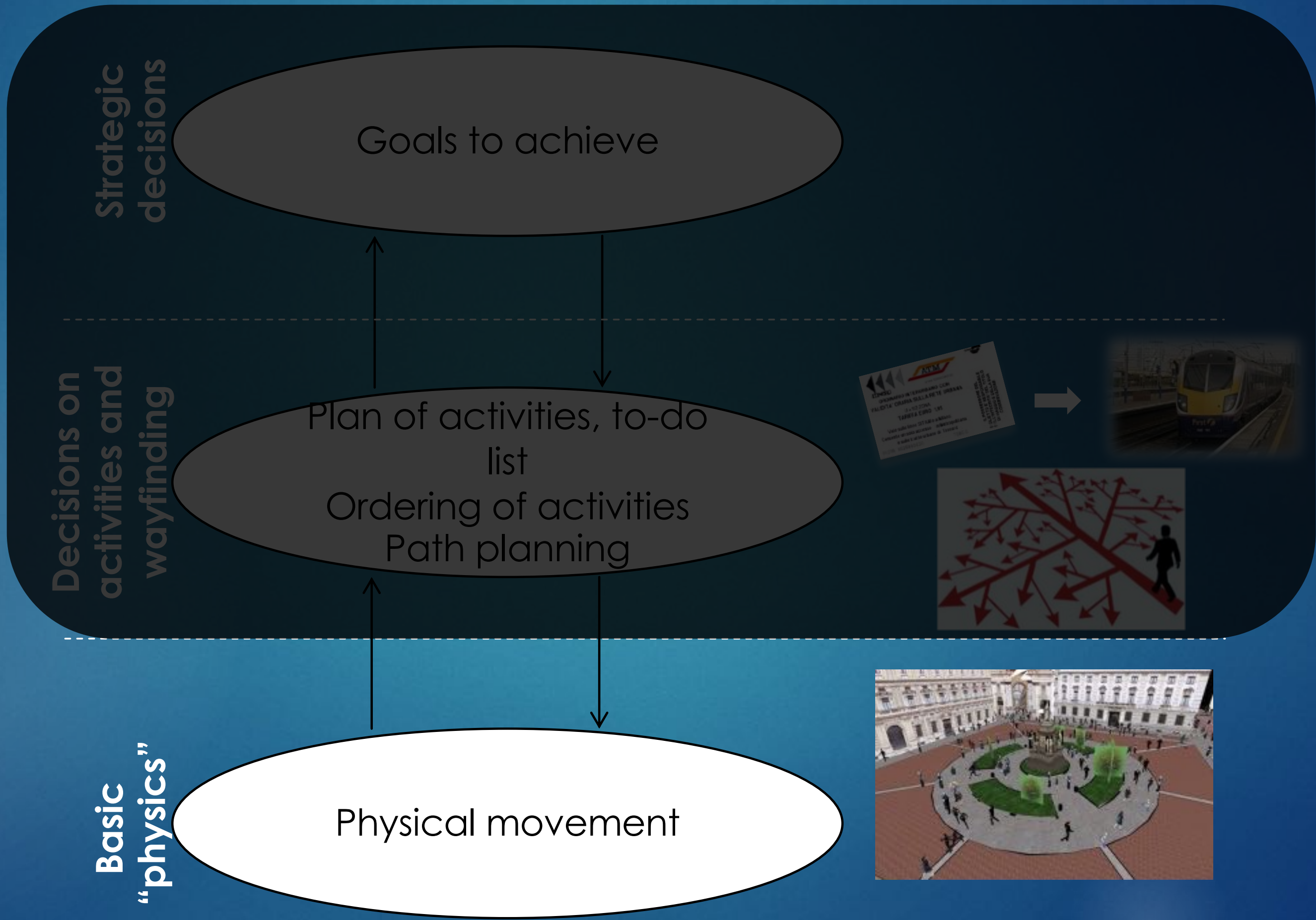


Navigli area

Studying crowds: analysis and synthesis (modeling and simulation)



What types of decisions we need to consider?



Physical movement

Considered aspects :

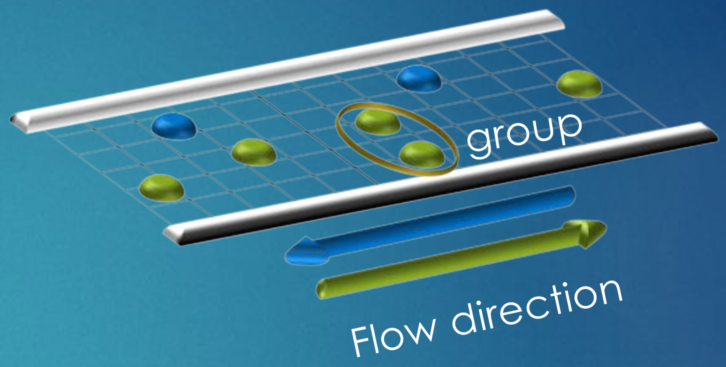
a) Goal of movement

b) Obstacles

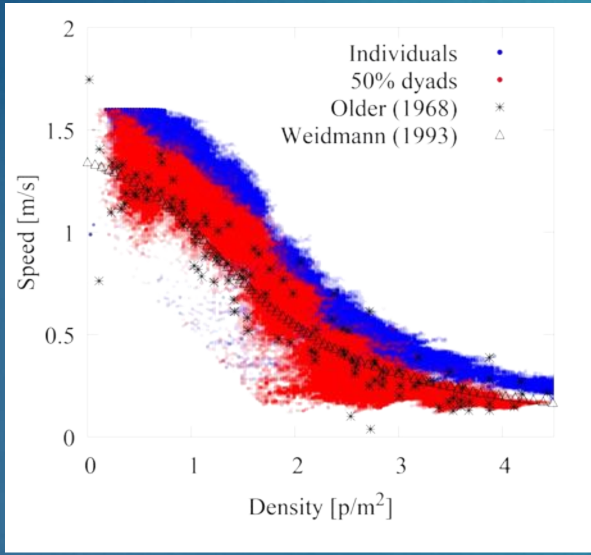
c) Members of own group

d) Other pedestrians

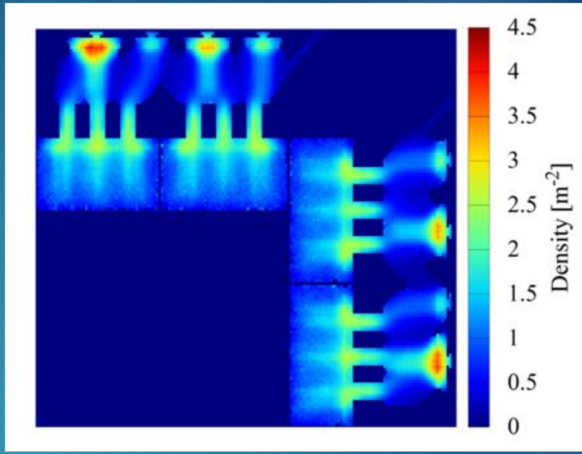
e) Current direction



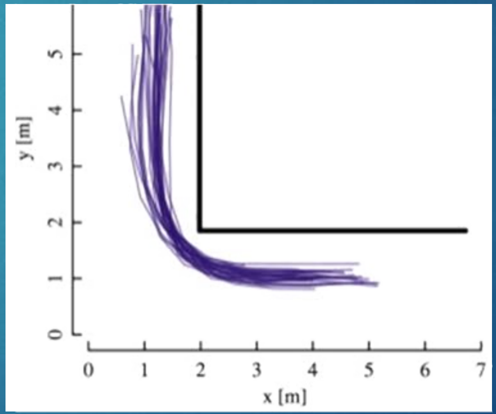
Validation



1. Fundamental diagram

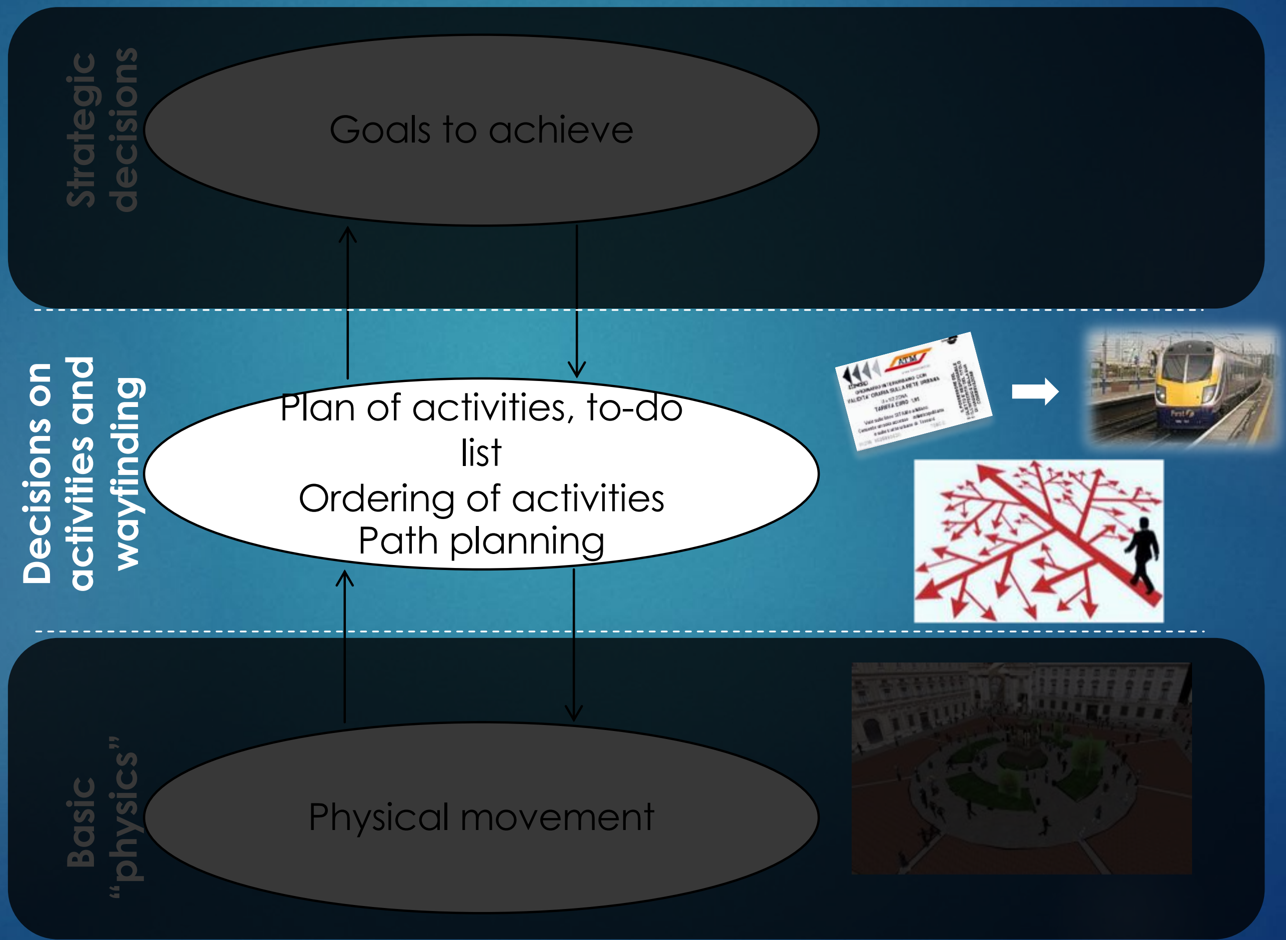


2. Local density maps



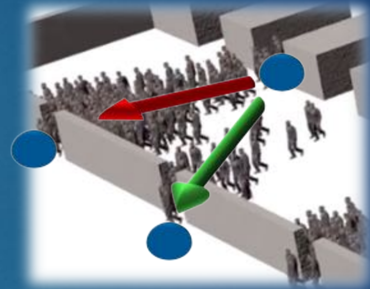
3. Trajectories and space utilization

Virtual crowds – different decisions and levels

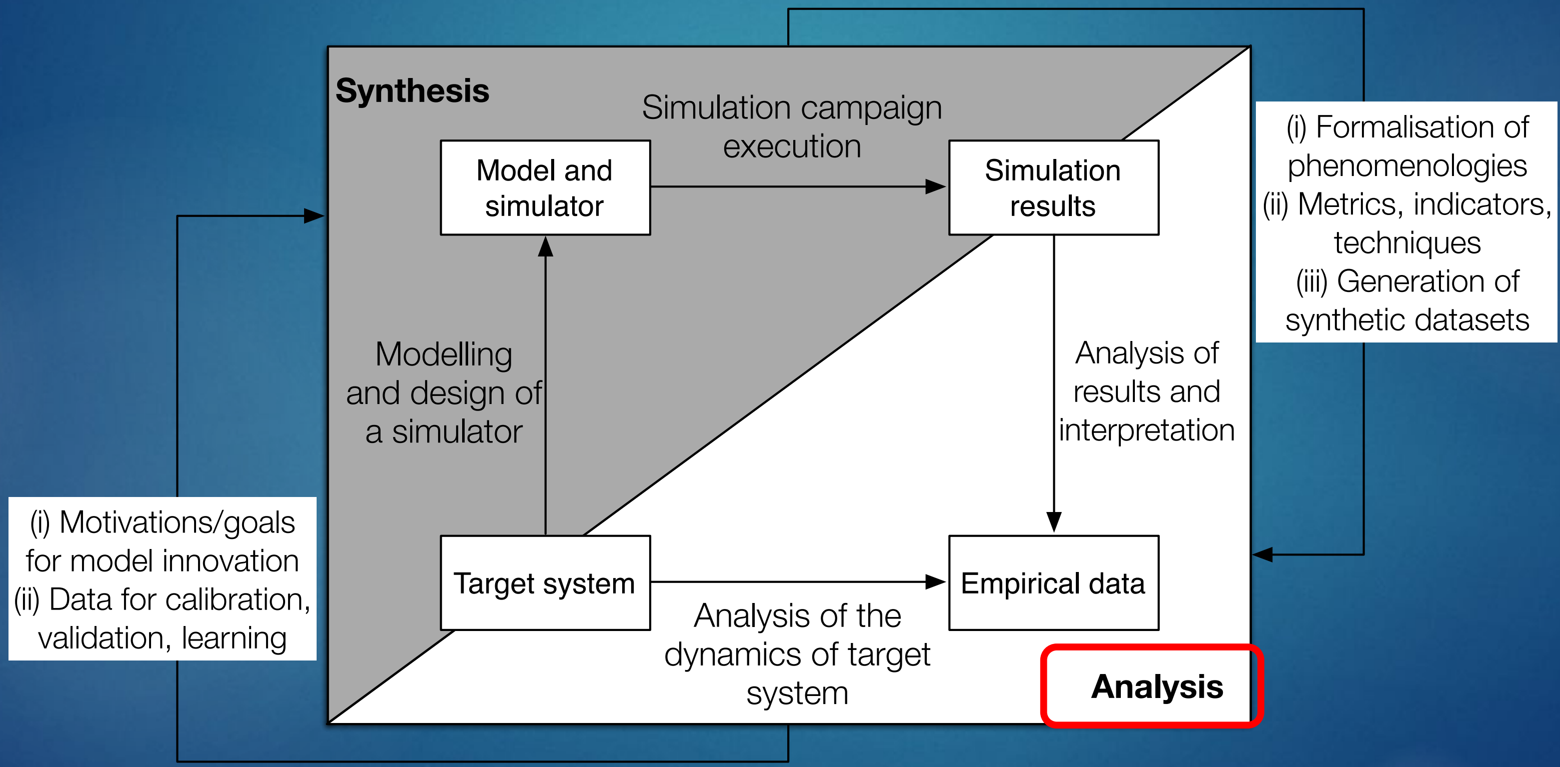


Wayfinding: alternative approaches

- Iterative approaches based on concepts of optimality/equilibrium
  - Local considerations (what I perceive here and now)
  - Global, although not current information (e.g. I know that generally at 5:30pm tangenziale is congested)
- Decision models based on currently available information, not requiring iterative executions of a model, possibly employing results of spatial cognition researches, insights from observations and experiments with pedestrians

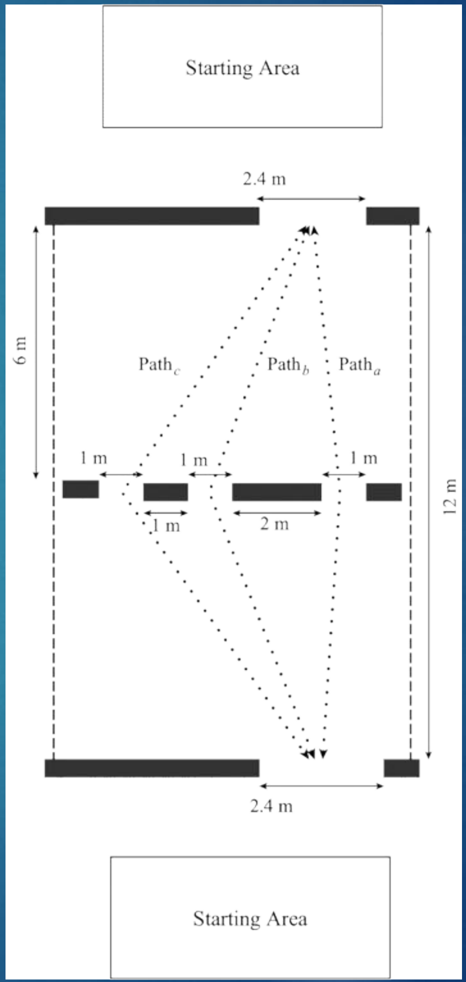


Studying crowds: analysis and synthesis (modeling and simulation)



Experimental observations of wayfinding (1)

- 46 male students participated
- Aiming to analyze the **impact of congested paths in the route choice**
- Three possible paths, activated according to the procedure:
  1. only $Path_a$ (to analyze completion times)
  2. two openings, $Path_a$ and $Path_b$
  3. two openings, $Path_a$ and $Path_c$
  4. all paths
- 4 iterations per procedure
- Participants have been asked to reach the opposite side
- Both sides of the scene were used as entrance/exit



Experimental observations of wayfinding (2)

- Pedestrians choosing longer paths ($Path_b$ and $Path_c$) generally enter the area before the gates on the left side (right in the reversed direction) → **length of path**
- Pedestrians choosing longer paths generally do so after some preceding ones have perceivably chosen the best path → **avoiding congestion**
- When choosing $Path_c$, many participants seem to *follow* persons before them → **following behavior**

Procedure 2

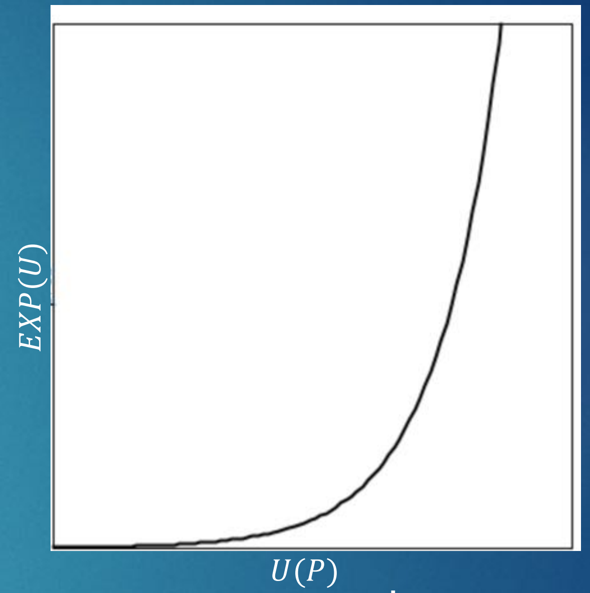
Procedure 3

Procedure 4

The route choice model – the utility function

- The probability to choose a path is exponentially dependent on the utility:

$$Prob(P) = N \cdot e^{U(P)}$$



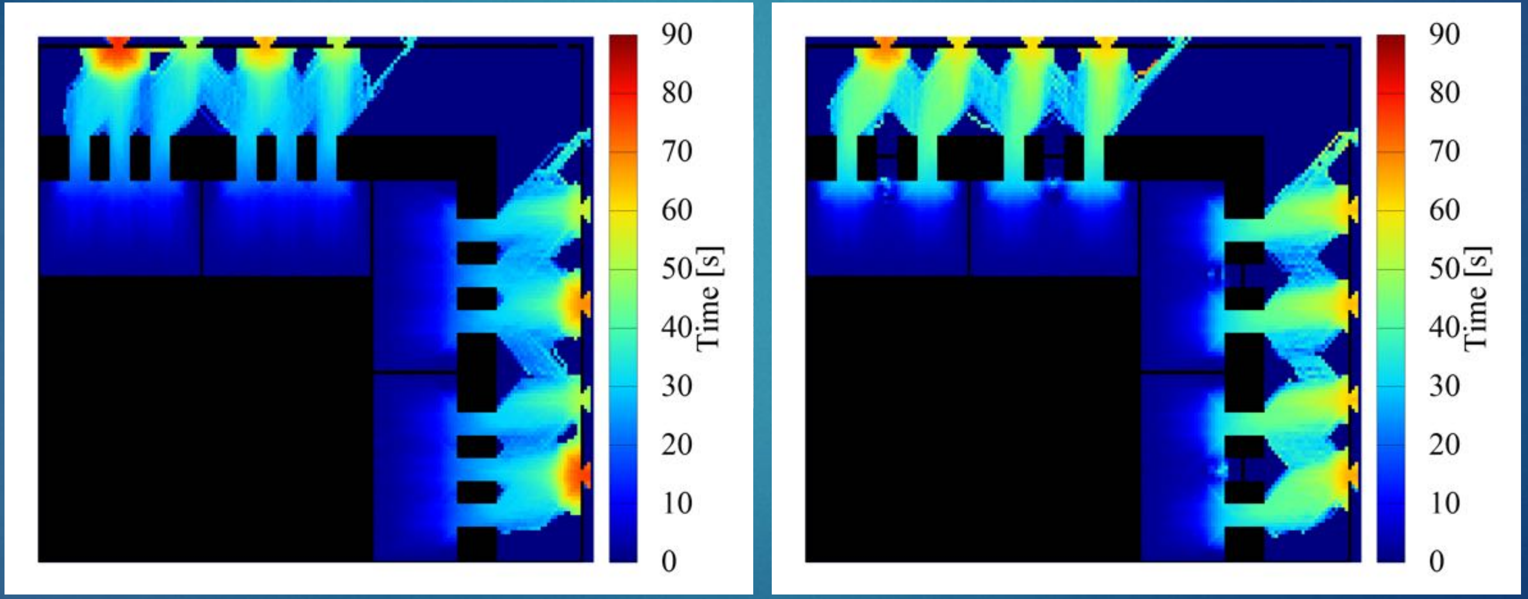
- The utility describes three evaluation components:

$$U(P) = \kappa_{tt} Eval_{tt}(P) - \kappa_q Eval_q(P) + \kappa_f Eval_f(P)$$

- The calibration is possible through the triple $(\kappa_{tt}, \kappa_q, \kappa_f)$

Putting it all together

Evacuation time maps



So what can be done about innovative mobility?

- These examples were a bit borderline, not exactly central to the topic, but useful to show how the methods can help
- Lots of things can be done more centrally:
  - Improve the performance of current services (e.g. Cai, Y., Ong, G. P., & Meng, Q. (2022). Dynamic bicycle relocation problem with broken bicycles. *Transportation Research Part E: Logistics and Transportation Review*, *165*, 102877)
  - Foresee and make what-if scenarios on slightly novel systems (Castagna, A., Guériau, M., Vizzari, G., & Dusparic, I. (2021). Demand-responsive rebalancing zone generation for reinforcement learning-based on-demand mobility. *AI Communications*, *34*(1), 73-88)
  - Study the demand, the potential acceptance for novel approaches…
- It takes a bit of creativity and passion

Thank you!

Giuseppe Vizzari