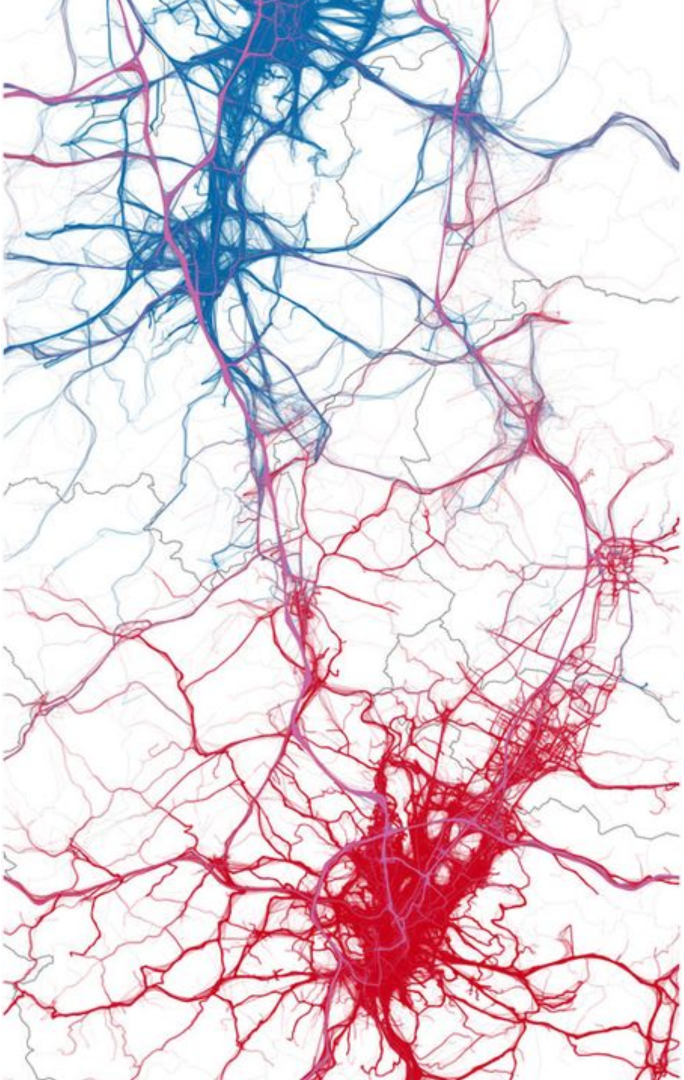


Consiglio Nazionale
delle Ricerche

01
Introduction

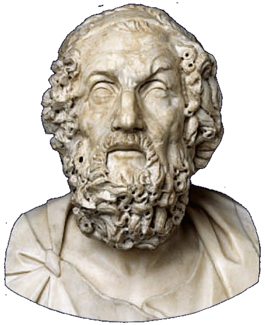
Geospatial Analytics

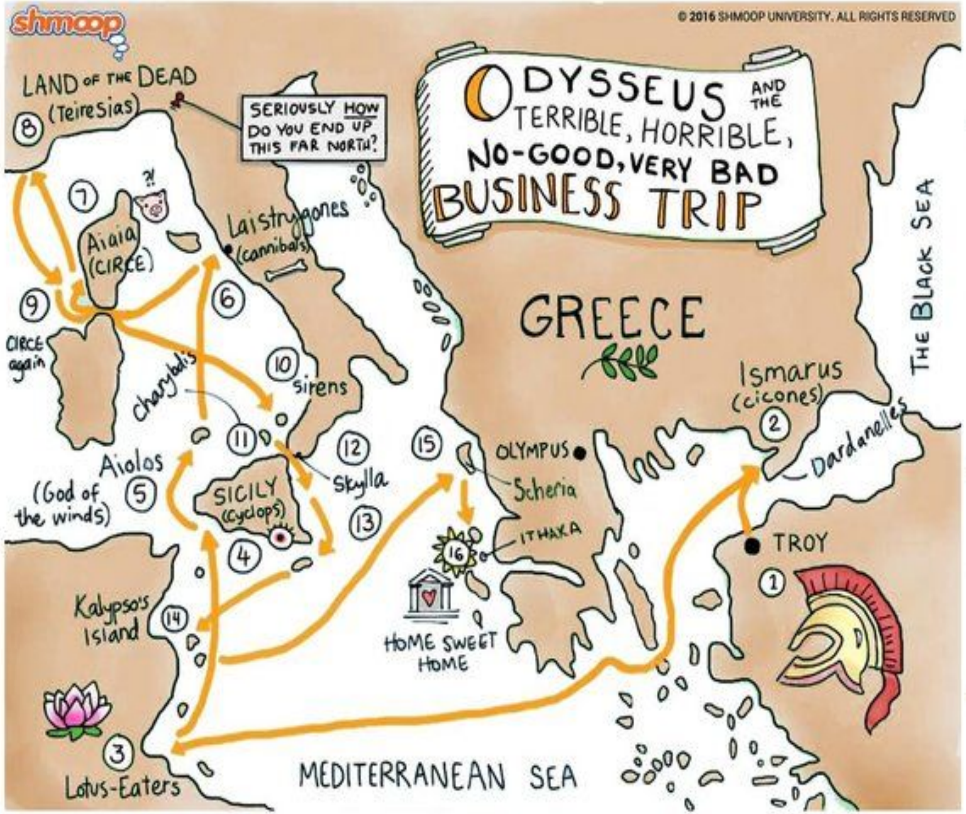
Transforming a (potentially large) set of isolated facts about ***when*** and ***where*** objects/people/phenomena **were** or **moved** into higher-level knowledge:

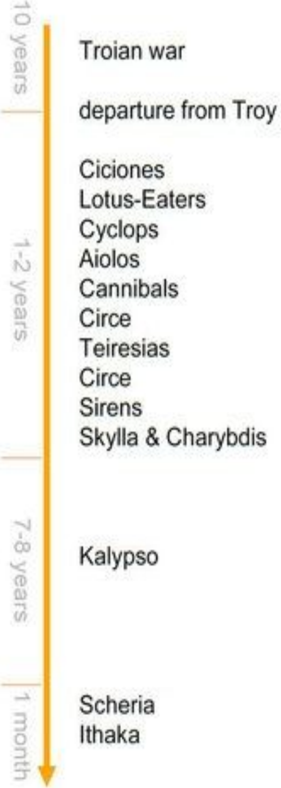
- Summarizing complex events and phenomena
- Providing insights about the general structure (global view)
- Identifying specific interesting patterns (local view)
- Enable predictions or educated guesses

Historical Examples

The Odyssey is the story of...a trajectory




shmoop
© 2016 SHMOOP UNIVERSITY. ALL RIGHTS RESERVED
ODYSSEUS AND THE TERRIBLE, HORRIBLE, NO-GOOD, VERY BAD BUSINESS TRIP
LAND OF THE DEAD (Teiresias) ⑧
SERIOUSLY HOW DO YOU END UP THIS FAR NORTH?
⑦ Aiaia (CIRCE)
Laistrygones (cannibals)
⑥
⑨ CIRCE again
⑩ sirens
Charybdis
⑪
⑫ Skylla
⑬
Aiolos (God of the winds) ⑤
SICILY (cyclops)
④
Kalypso's Island ⑭
③ Lotus-Eaters
MEDITERRANEAN SEA
⑮
OLYMPUS
Scheria
ITHAKA
⑯
HOME SWEET HOME
GREECE
THE BLACK SEA
Ismarus (cicones) ②
Dardanelles
TROY
①


10 years
1-2 years
7-8 years
1 month

Troian war

departure from Troy

Ciciones
Lotus-Eaters
Cyclops
Aiolos
Cannibals
Circe
Teiresias
Circe
Sirens
Skylla & Charybdis

Kalypso

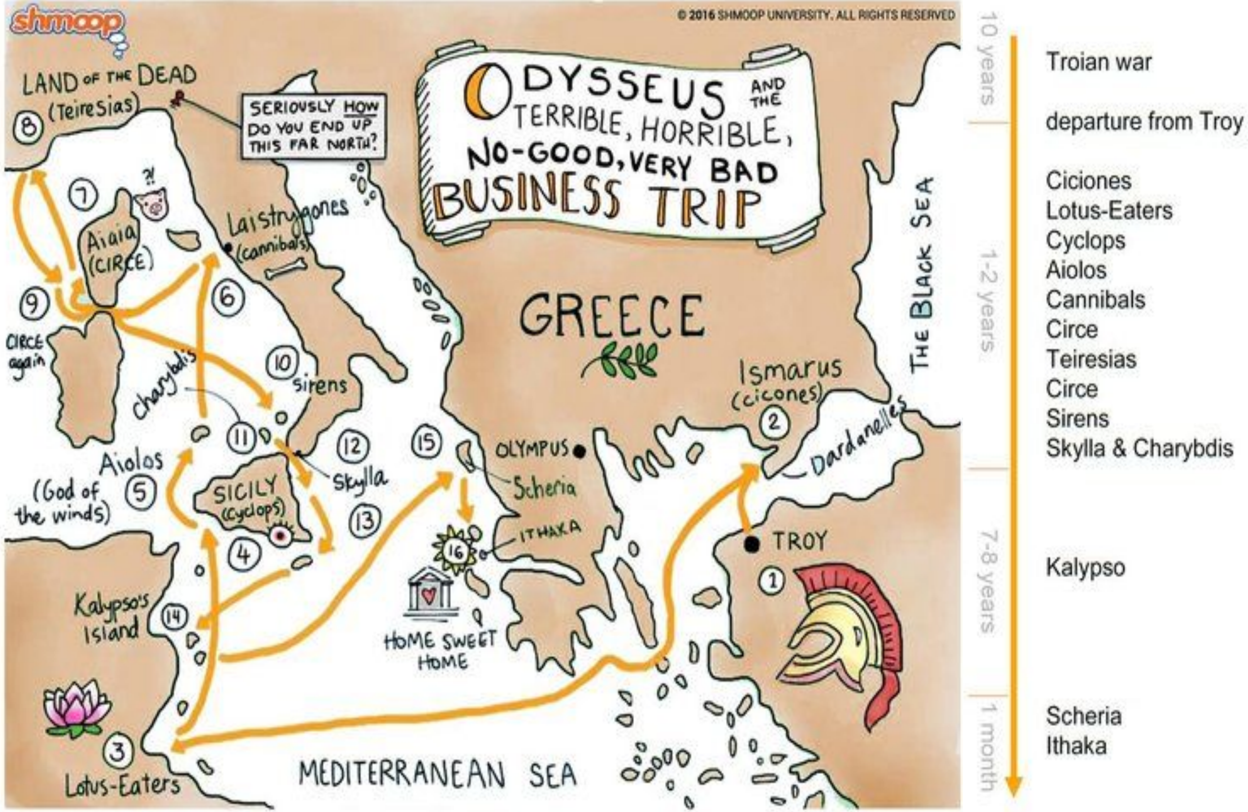
Scheria
Ithaka

"A man who has been through bitter experiences and travelled far enjoys even his sufferings after a time"

Homer, Odyssey

interactive map

The Odyssey is the story of...a trajectory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© 2016 SHMOOP UNIVERSITY. ALL RIGHTS RESERVED
ODYSSEUS AND THE TERRIBLE, HORRIBLE, NO-GOOD, VERY BAD BUSINESS TRIP
LAND OF THE DEAD
8 (Teiresias)
SERIOUSLY HOW DO YOU END UP THIS FAR NORTH?
7
Aiaia (CIRCE)
Laistrygones (cannibals)
6
9
CIRCE again
Charybdis
10
sirens
11
12
Skylla
13
Aiolos (God of the winds) 5
SICILY (cyclops)
4
15
Scheria
OLYMPUS
GREECE
Ismarus (cicones)
2
Dardanelles
THE BLACK SEA
TROY
1
16
ITHAKA
HOME SWEET HOME
Kalypso's Island
14
3
Lotus-Eaters
MEDITERRANEAN SEA
10 years
1-2 years
7-8 years
1 month

Troian war
departure from Troy

Ciciones
Lotus-Eaters
Cyclops
Aiolos
Cannibals
Circe
Teiresias
Circe
Sirens
Skylla & Charybdis

Kalypso

Scheria
Ithaka

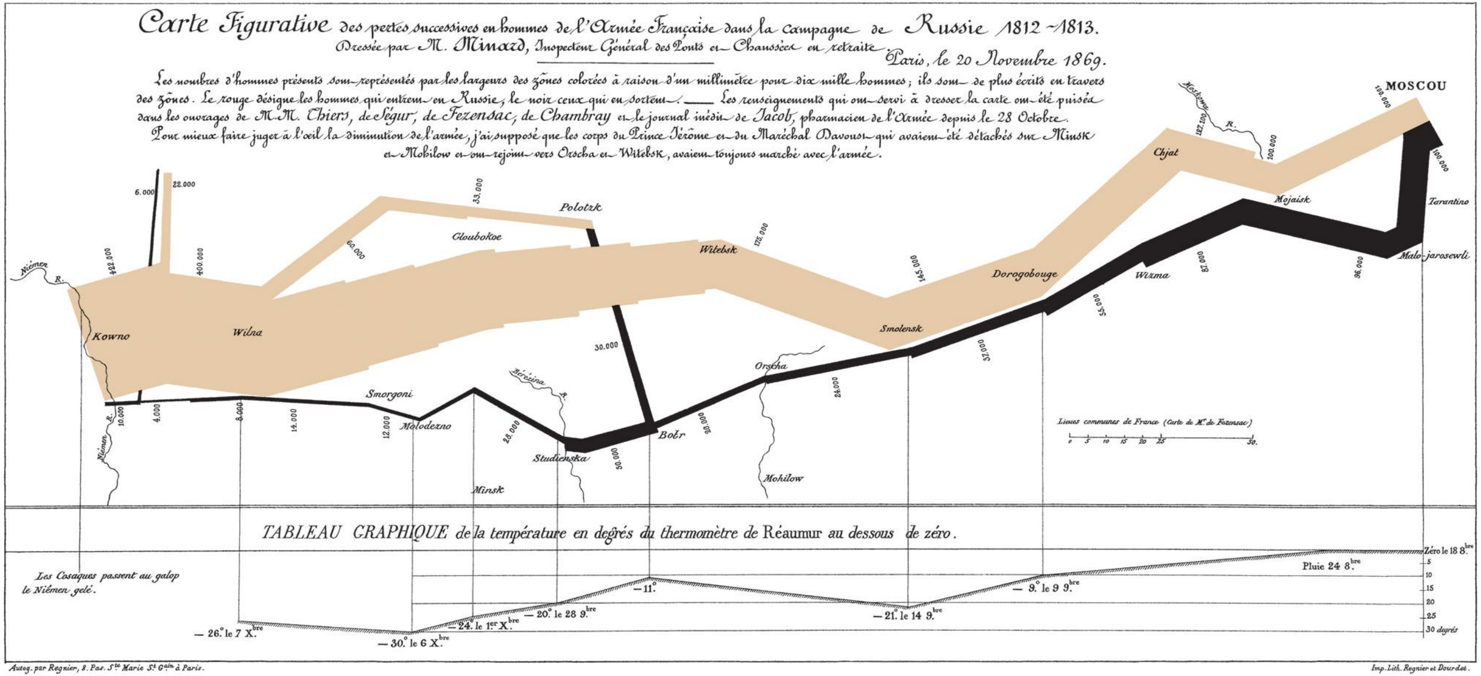
“ma misi me per l’alto mare aperto
sol con un legno e con quella compagna
picciola da la qual non fui diserto.
L’un lito e l’altro vidi infin la Spagna,
fin nel Morrocco, e l’isola d’i Sardi,
e l’altre che quel mare intorno bagna.”

Dante’s Inferno, Canto XXVI

interactive map

French army in the Russian campaign (1812-1813)

Charles Minard, 1869



Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813.

Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite.

Paris, le 20 Novembre 1869.

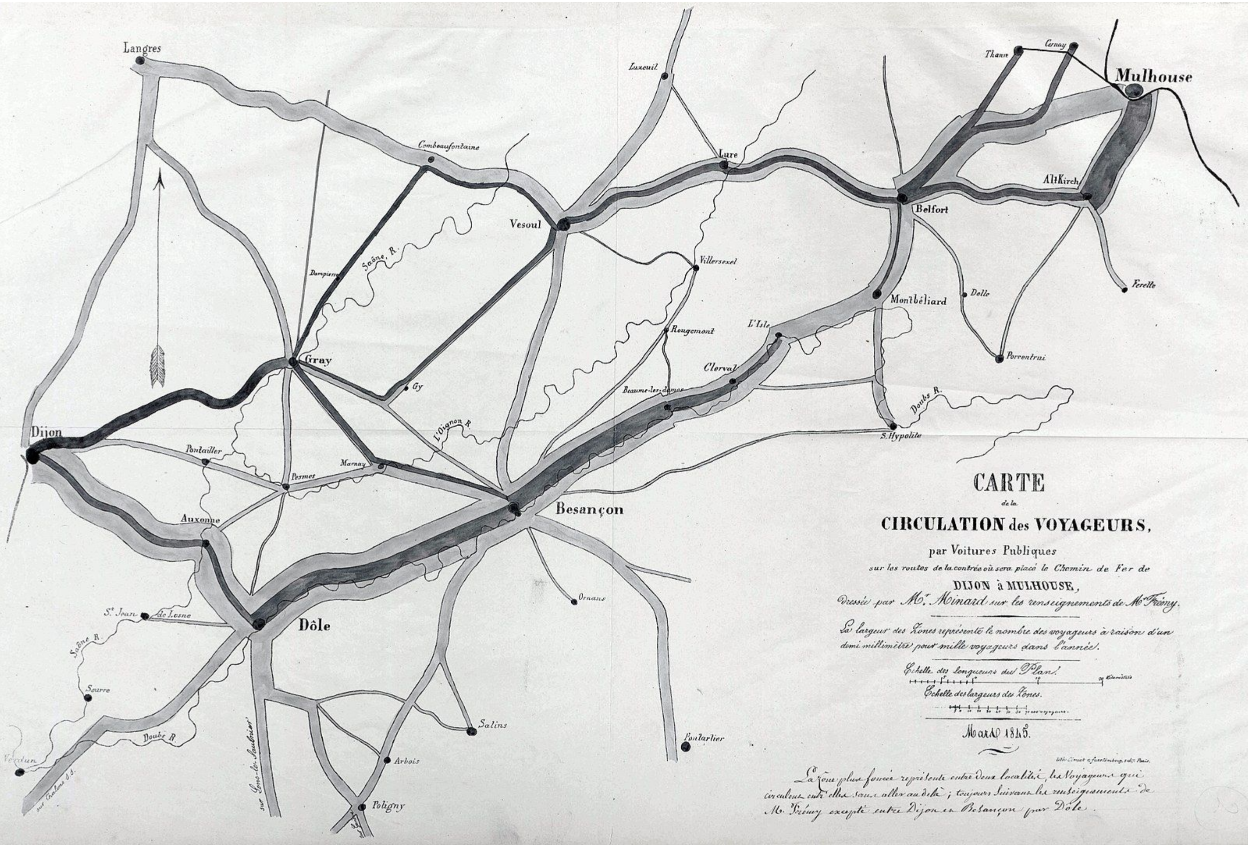
Les nombres d'hommes présents sont représentés par les largeurs des zônes colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en travers des zônes. Le rouge désigne les hommes qui entrent en Russie, le noir ceux qui en sortent. —— Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M.M. Thiers, de Ségur, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre.

Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mobilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.

TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.

Les Cosaques passent au galop le Niémen gelé.

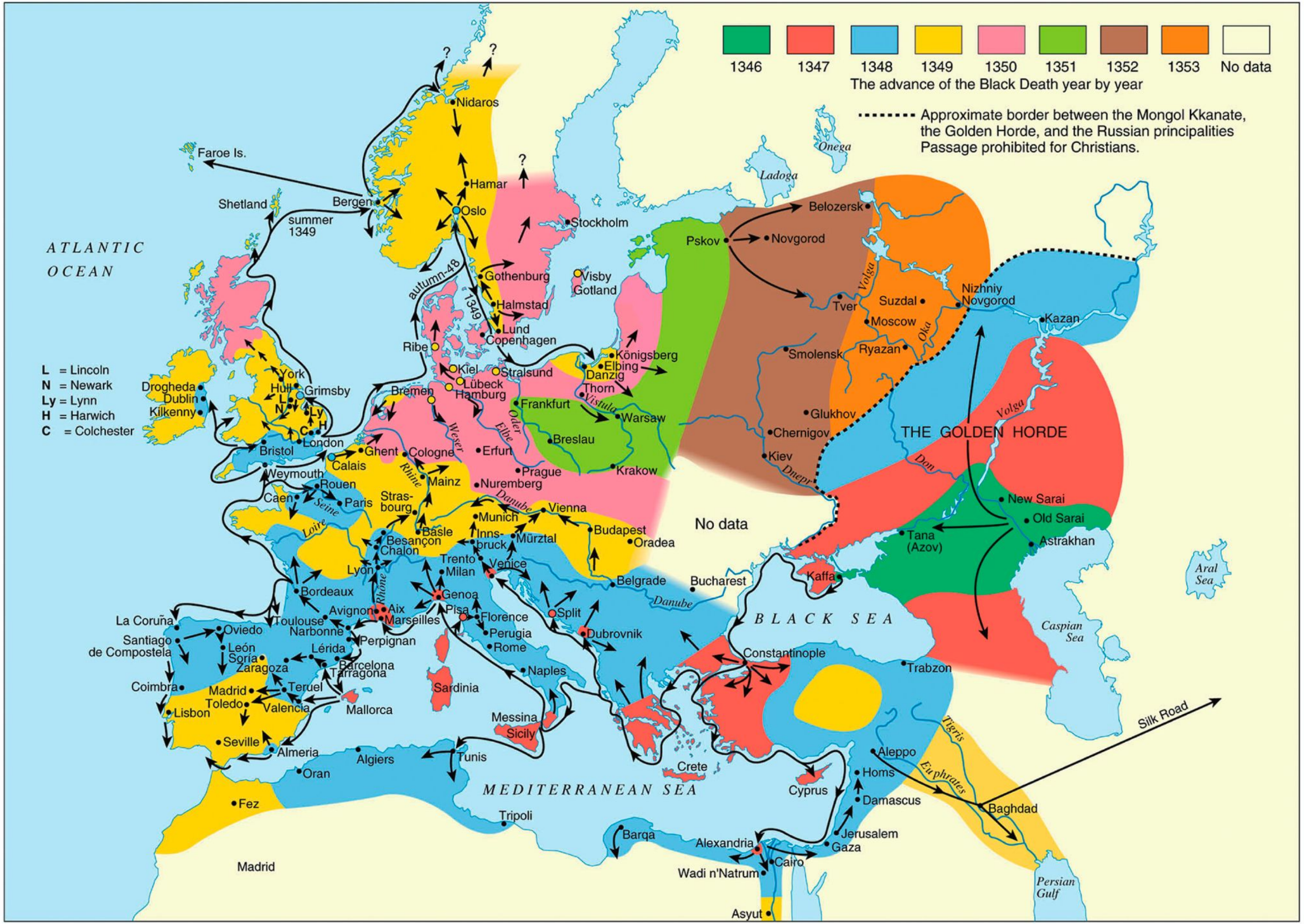
MOSCOU
Moskowa
R.
Chjat
Mojaisk
Tarantino
Malo-jarosewli
Wixma
Dorogobouge
Smolensk
Orscha
Mohilow
Witebsk
Polotzk
Gloubokoe
Bobr
Studienska
Bérézina R.
Minsk
Molodezno
Smorgoni
Wilna
Kowno
Niémen R.
422.000
400.000
22.000
6.000
60.000
33.000
175.000
145.000
127.100
100.000
100.000
96.000
87.000
55.000
37.000
24.000
20.000
50.000
30.000
28.000
12.000
14.000
8.000
4.000
10.000
Lieues communes de France (Carte de M.r de Fezensac)
0 5 10 15 20 25 50
Zéro le 18 8.bre
Pluie 24 8.bre
— 9.° le 9 9.bre
— 21.° le 14 9.bre
— 11.°
— 20.° le 28 9.bre
— 24.° le 1.er X.bre
— 30.° le 6 X.bre
— 26.° le 7 X.bre
5
10
15
20
25
30 degrés
Autog. par Regnier, 8. Pas. S.te Marie S.t G.ain à Paris.
Imp. Lith. Regnier et Dourdet.

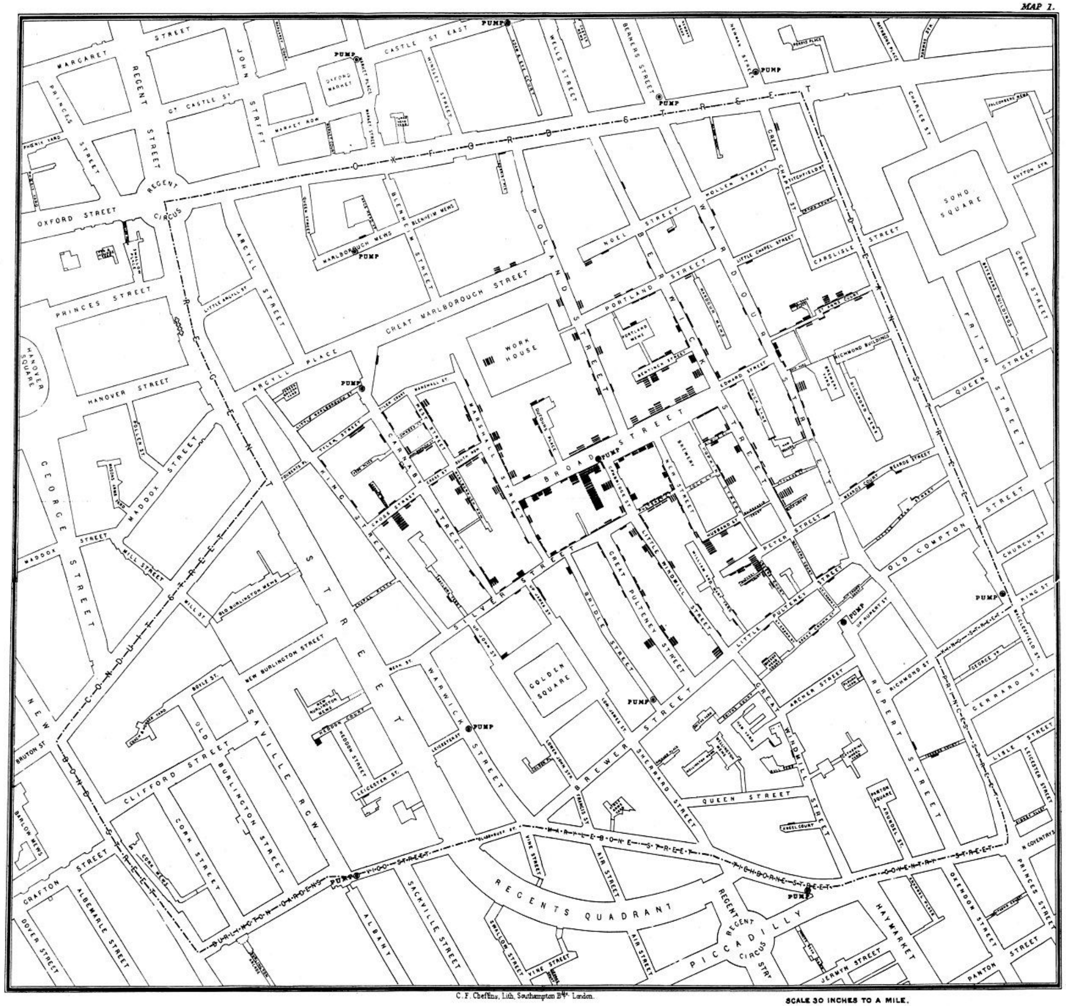

CARTE
de la
CIRCULATION des VOYAGEURS,
par Voitures Publiques
sur les routes de la contrée où sera placé le Chemin de Fer de
DIJON à MULHOUSE,
dressée par Mr. Minard sur les renseignements de Mr. Frémy.
La largeur des Zones représente le nombre des voyageurs à raison d'un demi millimètre pour mille voyageurs dans l'année.
Echelle des longueurs du Plan.
Kilomètres
Echelle des largeurs des Zones.
voyageurs.
Mars 1845.
La Zone plus foncée représente entre deux localités les Voyageurs qui circulent entre elles sans aller au delà ; toujours suivant les renseignements de M. Frémy excepté entre Dijon et Besançon par Dôle.
Langres
Luxeuil
Thann
Cernay
Mulhouse
Combeaufontaine
Lure
Vesoul
AltKirch
Belfort
Villersexel
Dampierre
Saône R.
Montbéliard
Delle
Ferette
Rougemont
L'Isle
Porrentrui
Gray
Gy
Clerval
Beaume-les-dames
Doubs R.
Dijon
L'Oignon R.
S. Hypolite
Pontailler
Marnay
Pesmes
Besançon
Auxonne
Ornans
St. Jean de Losne
Dôle
Saône R.
Seurre
Salins
Pontarlier
Doubs R.
Verdun
Arbois
Poligny

Number of passengers between Dijon and Mulhouse

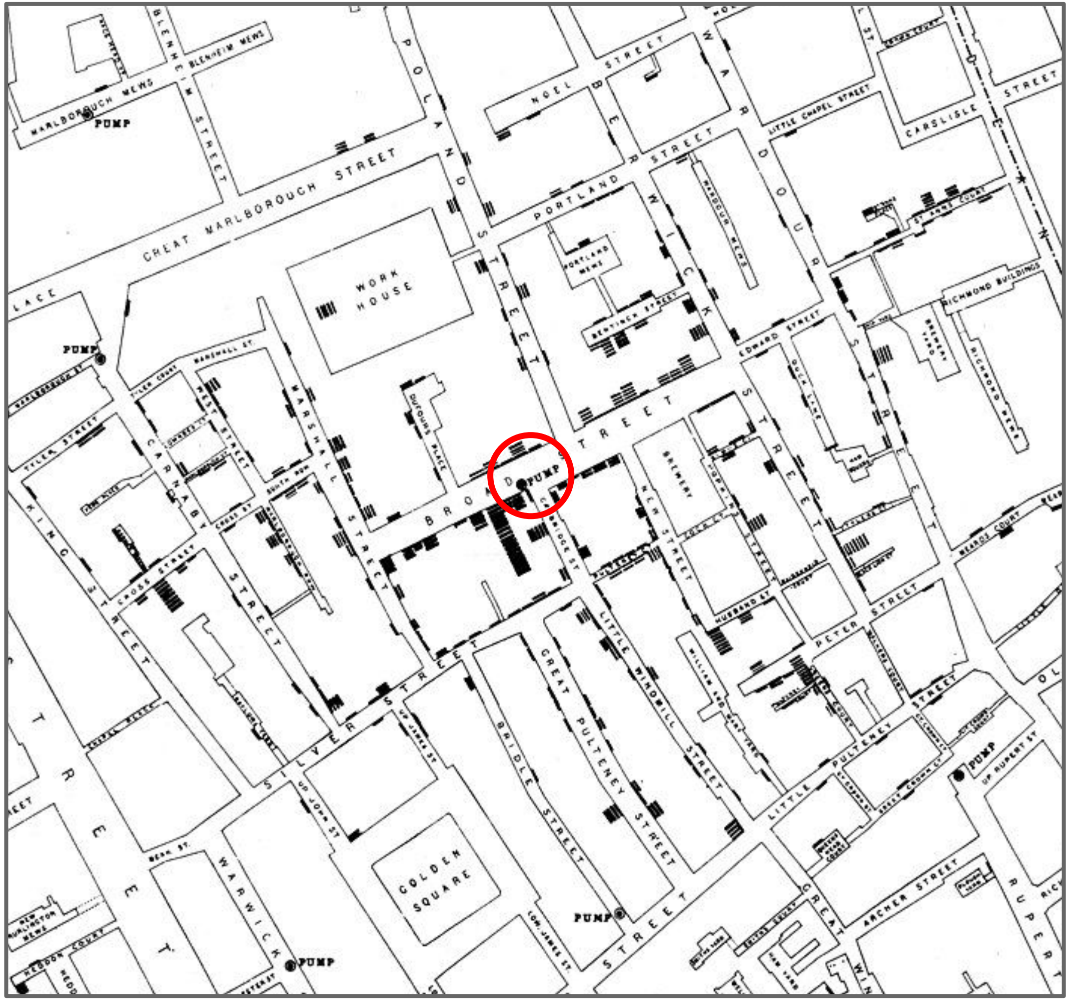
Charles Minard, 1845

Spread of the Black Death (1346–1353)


1346
1347
1348
1349
1350
1351
1352
1353
No data
The advance of the Black Death year by year
Approximate border between the Mongol Kkanate, the Golden Horde, and the Russian principalities
Passage prohibited for Christians.
L = Lincoln
N = Newark
Ly = Lynn
H = Harwich
C = Colchester
ATLANTIC OCEAN
Faroe Is.
Shetland
summer 1349
Bergen
Nidaros
Hamar
Oslo
autumn-48
1349
Gothenburg
Halmstad
Lund
Copenhagen
Stockholm
Visby
Gotland
Onega
Ladoga
Belozersk
Pskov
Novgorod
Tver
Volga
Suzdal
Moscow
Nizhniy Novgorod
Kazan
Oka
Ryazan
Smolensk
Königsberg
Elbing
Danzig
Thorn
Vistula
Warsaw
Glukhov
Chernigov
Kiev
Dnepr
THE GOLDEN HORDE
Don
New Sarai
Old Sarai
Astrakhan
Tana (Azov)
Kaffa
Aral Sea
Caspian Sea
Drogheda
Dublin
Kilkenny
York
Hull
Grimsby
London
Bristol
Weymouth
Ribe
Kiel
Stralsund
Lübeck
Hamburg
Bremen
Frankfurt
Oder
Elbe
Weser
Breslau
Krakow
Erfurt
Prague
Calais
Ghent
Cologne
Rhine
Mainz
Nuremberg
Danube
Vienna
Caen
Rouen
Paris
Seine
Loire
Strasbourg
Basle
Munich
Innsbruck
Mürztal
Budapest
Oradea
No data
Besançon
Chalon
Lyon
Rhone
Trento
Milan
Venice
Bordeaux
Avignon
Aix
Marseilles
Genoa
Pisa
Florence
Perugia
Rome
Split
Dubrovnik
Belgrade
Danube
Bucharest
BLACK SEA
Constantinople
Trabzon
La Coruña
Santiago de Compostela
Oviedo
León
Soria
Zaragoza
Toulouse
Narbonne
Perpignan
Lérida
Barcelona
Tarragona
Coimbra
Madrid
Toledo
Teruel
Valencia
Lisbon
Seville
Almeria
Mallorca
Sardinia
Naples
Messina
Sicily
Tunis
Algiers
Oran
Fez
Madrid
MEDITERRANEAN SEA
Tripoli
Crete
Cyprus
Aleppo
Homs
Damascus
Jerusalem
Gaza
Tigris
Euphrates
Baghdad
Silk Road
Barqa
Alexandria
Cairo
Wadi n'Natrum
Asyut
Persian Gulf
?


MAP 1.
OXFORD STREET
REGENT STREET
GREAT MARLBOROUGH STREET
BROAD STREET
WORK HOUSE
SOHO SQUARE
GOLDEN SQUARE
BERWICK STREET
POLAND STREET
DEAN STREET
WARDOUR STREET
OLD COMPTON STREET
PUMP
REGENTS QUADRANT
PICCADILLY
PICCADILLY CIRCUS
CONDUIT STREET
HANOVER SQUARE
C.F. Cheffins, Lith, Southampton Bldgs London.
SCALE 30 INCHES TO A MILE.

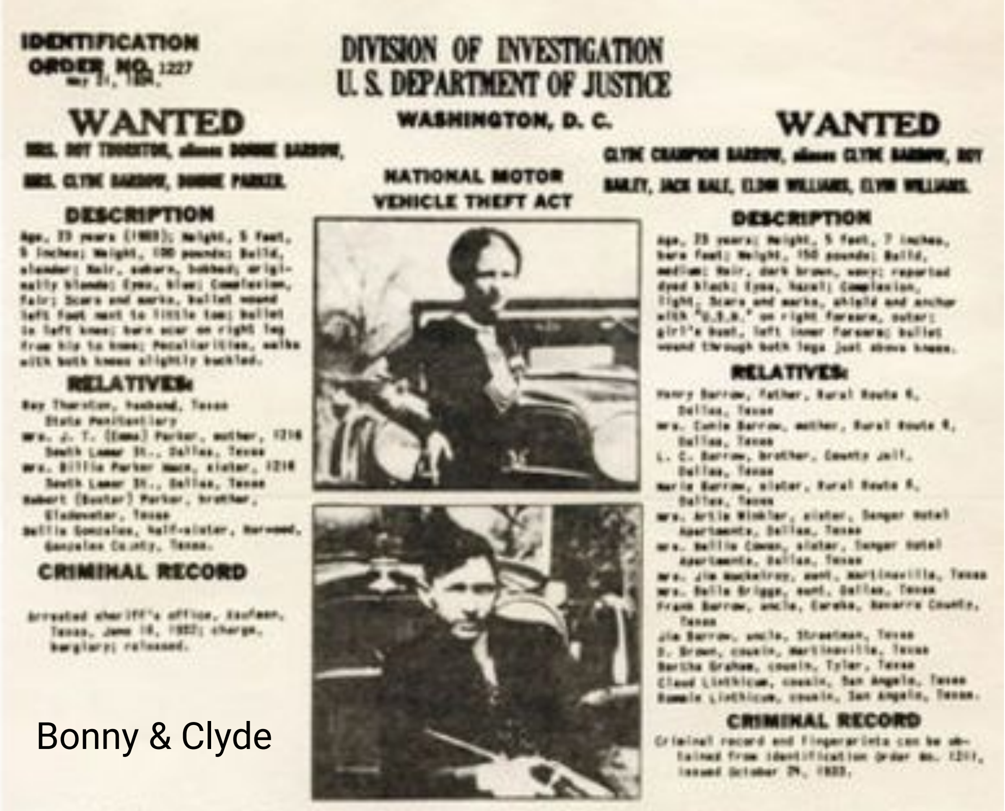
John Snow and the Broad Street cholera outbreak (1854)


BLENHEIM MEWS
MARLBOROUGH MEWS
PUMP
GREAT MARLBOROUGH STREET
POLAND STREET
NOEL STREET
BERWICK STREET
PORTLAND STREET
WARDOUR STREET
LITTLE CHAPEL STREET
CARLISLE STREET
DEAN STREET
WORK HOUSE
PORTLAND MEWS
BENTINCK STREET
RICHMOND BUILDINGS
EDWARD STREET
PUMP
MARSHALL STREET
CARNABY STREET
DUFOURS PLACE
BROAD STREET
PUMP
CAMBRIDGE ST
NEW STREET
BREWERY
KING STREET
CROSS STREET
TYLER STREET
SILVER STREET
HUSBAND ST
PETER STREET
GREAT PULTENEY STREET
LITTLE WINDMILL STREET
BRIDLE STREET
LITTLE PULTENEY STREET
GREAT CROWN CT
PUMP
UP RUPERT ST
RUPERT STREET
GOLDEN SQUARE
WARWICK STREET
REGENT STREET
PUMP
PUMP
BRIDLE LANE
ARCHER STREET
GREAT WINDMILL STREET

John Snow and the Broad Street cholera outbreak (1854)

Predicting criminals' trajectory

1930s



IDENTIFICATION
ORDER NO. 1227

DIVISION OF INVESTIGATION
U. S. DEPARTMENT OF JUSTICE
WASHINGTON, D. C.

WANTED

NATIONAL MOTOR
VEHICLE THEFT ACT

WANTED

DESCRIPTION

RELATIVES:

CRIMINAL RECORD

DESCRIPTION

RELATIVES:

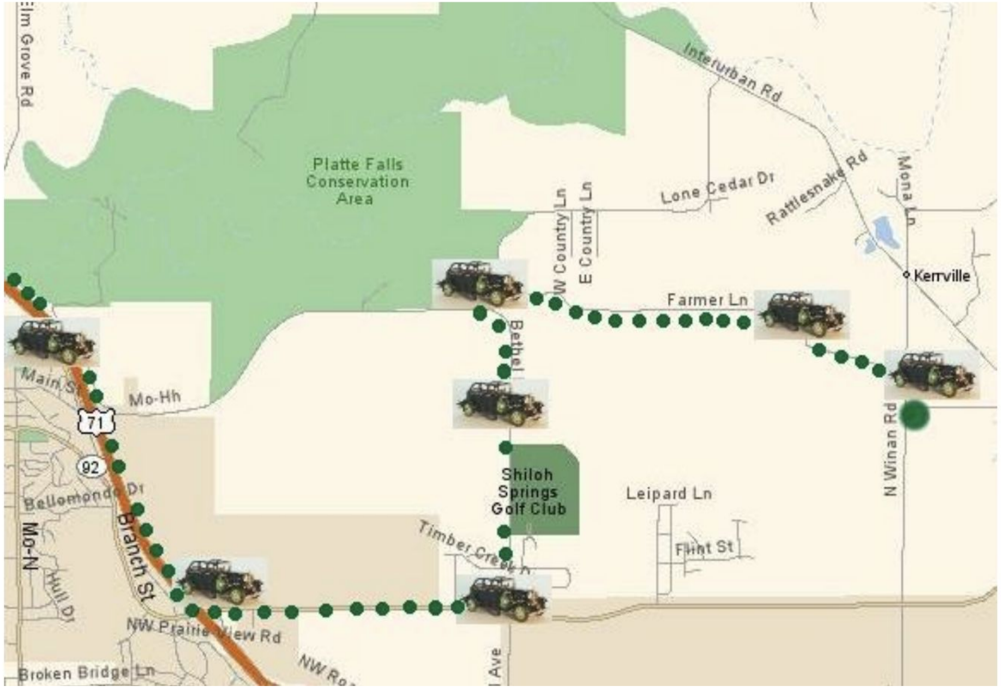
CRIMINAL RECORD

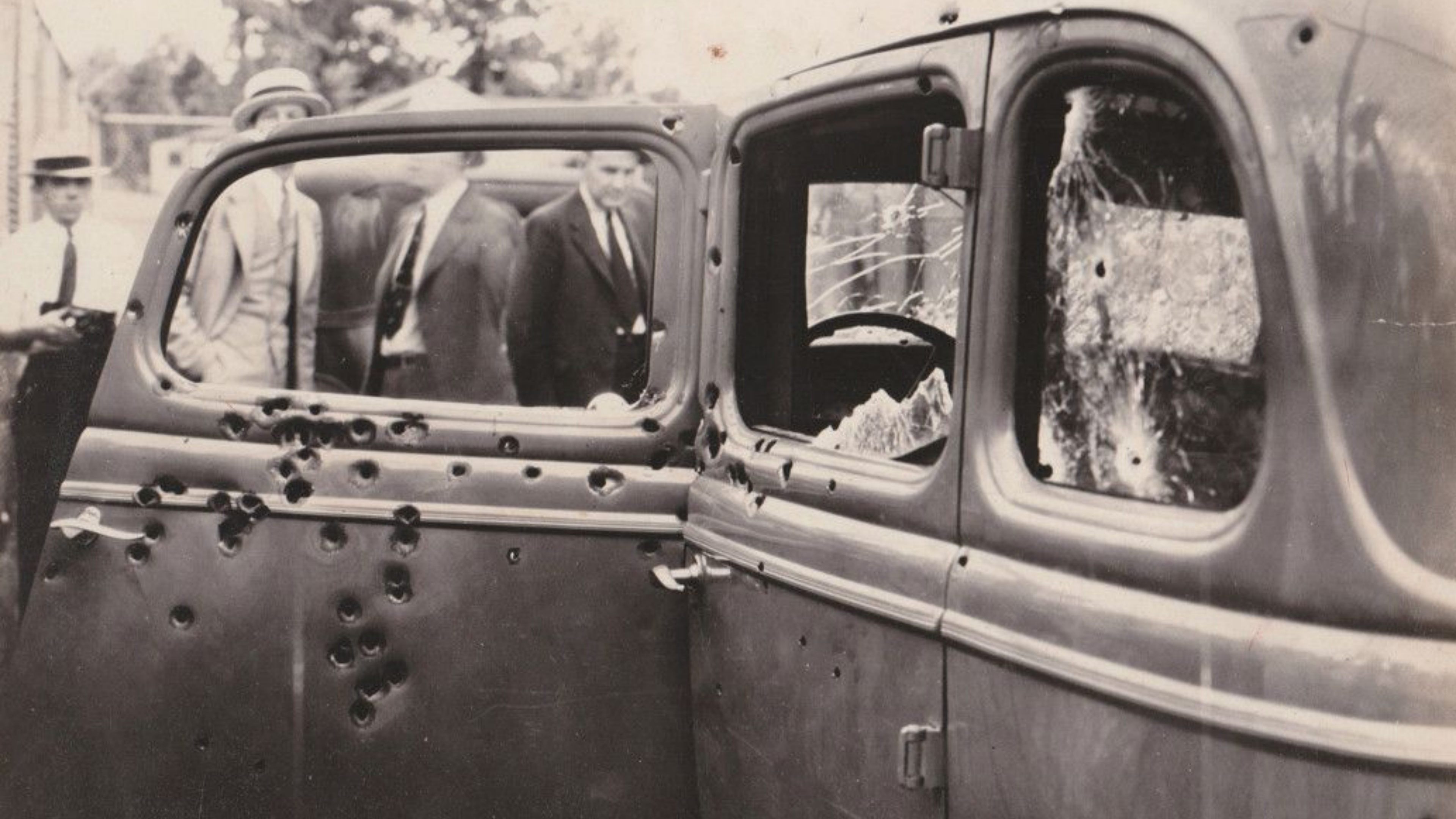
Bonny & Clyde

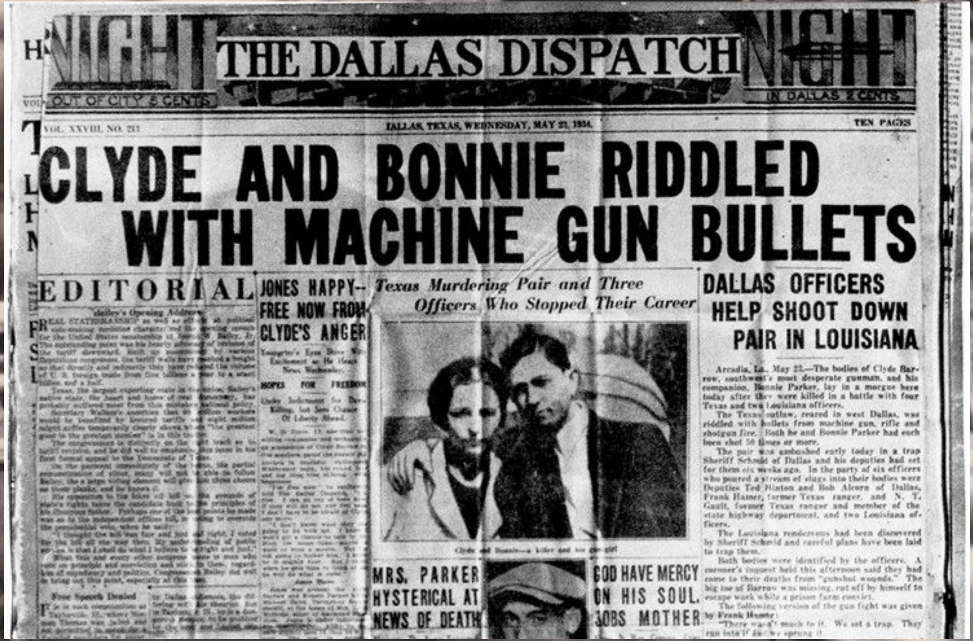
Predicting criminals' trajectory

1930s

The Bonny & Clyde task force


Elm Grove Rd
Interurban Rd
Platte Falls Conservation Area
Lone Cedar Dr
Rattlesnake Rd
Mona Ln
W Country Ln
E Country Ln
Kerrville
Farmer Ln
Bethel
Main St
Mo-Hh
71
92
Bellomondo Dr
Branch St
Mo-N
Hull Dr
Shiloh Springs Golf Club
Leipard Ln
Flint St
Timber Creek
N Winan Rd
NW Prairie View Rd
Broken Bridge Ln





NIGHT THE DALLAS DISPATCH NIGHT
OUT OF CITY 5 CENTS
IN DALLAS 2 CENTS
VOL. XXVIII, NO. 213
DALLAS, TEXAS, WEDNESDAY, MAY 23, 1934.
TEN PAGES

CLYDE AND BONNIE RIDDLED WITH MACHINE GUN BULLETS

EDITORIAL

Bailey's Opening Address

Free Speech Denied

JONES HAPPY— FREE NOW FROM CLYDE'S ANGER

HOPES FOR FREEDOM

Texas Murdering Pair and Three Officers Who Stopped Their Career

Clyde and Bonnie—a killer and his gun girl

MRS. PARKER HYSTERICAL AT NEWS OF DEATH

GOD HAVE MERCY ON HIS SOUL, SOBS MOTHER

DALLAS OFFICERS HELP SHOOT DOWN PAIR IN LOUISIANA

Arcadia, La., May 23.—The bodies of Clyde Barrow, southwest's most desperate gunman, and his companion, Bonnie Parker, lay in a morgue here today after they were killed in a battle with four Texas and two Louisiana officers.

The Texas outlaw, reared in west Dallas, was riddled with bullets from machine gun, rifle and shotgun fire. Both he and Bonnie Parker had each been shot 50 times or more.

The pair was ambushed early today in a trap Sheriff Schmid of Dallas and his deputies had set for them six weeks ago. In the party of six officers who poured a stream of slugs into their bodies were Deputies Ted Hinton and Bob Alcorn of Dallas, Frank Hamer, former Texas ranger, and N. T. Gault, former Texas ranger and member of the state highway department, and two Louisiana officers.

The Louisiana rendezvous had been discovered by Sheriff Schmid and careful plans have been laid to trap them.

Both bodies were identified by the officers. A coroner's inquest held this afternoon said they had come to their deaths from "gunshot wounds." The big toe of Barrow was missing, cut off by himself to escape work while a prison farm convict.

The following version of the gun fight was given by Frank Hamer:

"There wasn't much to it. We set a trap. They ran into it and we sprung it.

Tracking the movements of dissidents

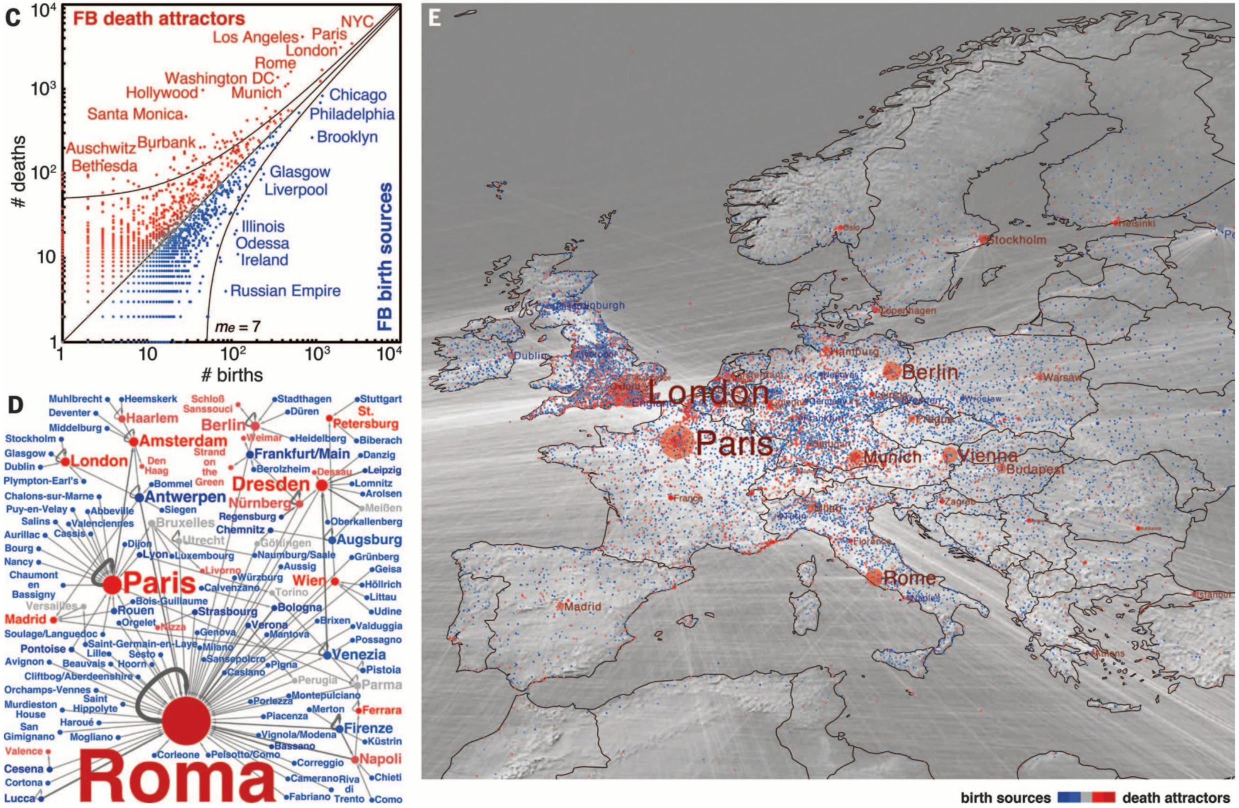
1970s-1980s

MINISTERIUM FÜR STAATSSICHERHEIT

- Stasi sprayed a ***radioactive solution*** on the floors of the rooms where suspected dissidents met
- The solution adhered to dissidents' shoes, allowing agents to **track who attended a meeting** there
- Agents wore portable Geiger counters that activate when a suspected dissident was nearby

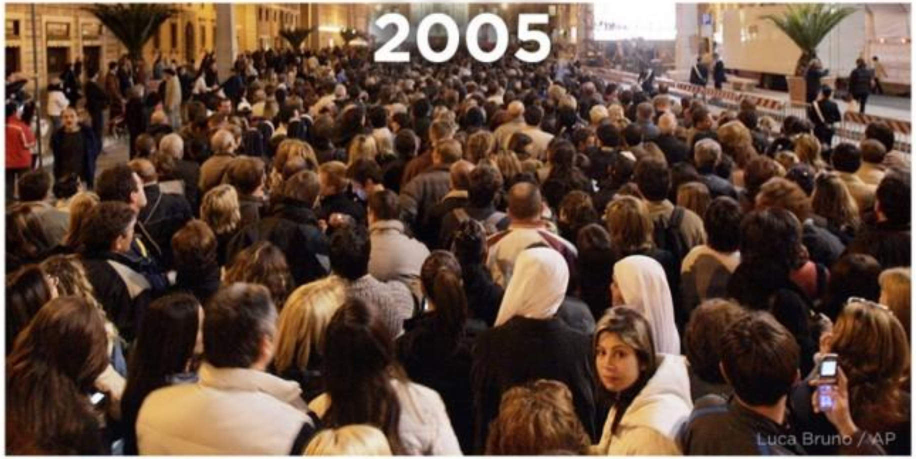
NewScientist

Birth and death place of notable individuals



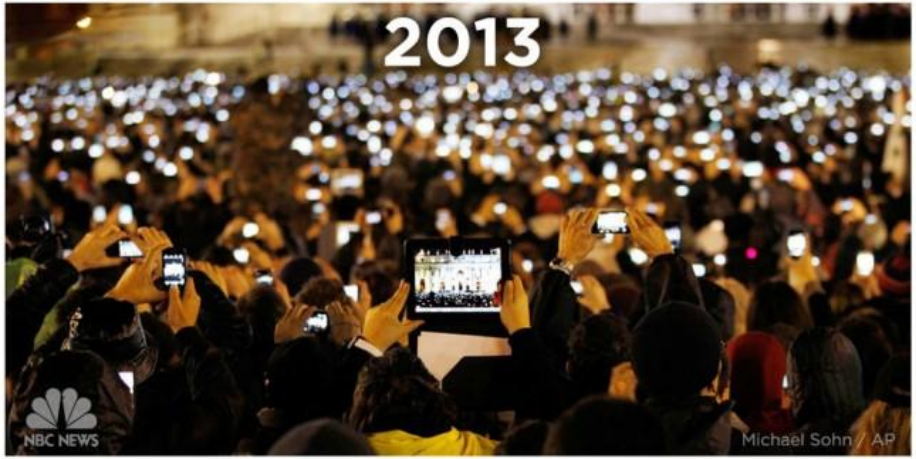
- (C) Birth-death locations scatter plot, cumulated over all time with outliers colored as birth sources (blue) and death attractors (red)
- (D) Illustration of birth-death flows of antiquarians in the 18th century
- (E) Migration in Europe, with node size corresponding to PageRank

The Big Data era



2005

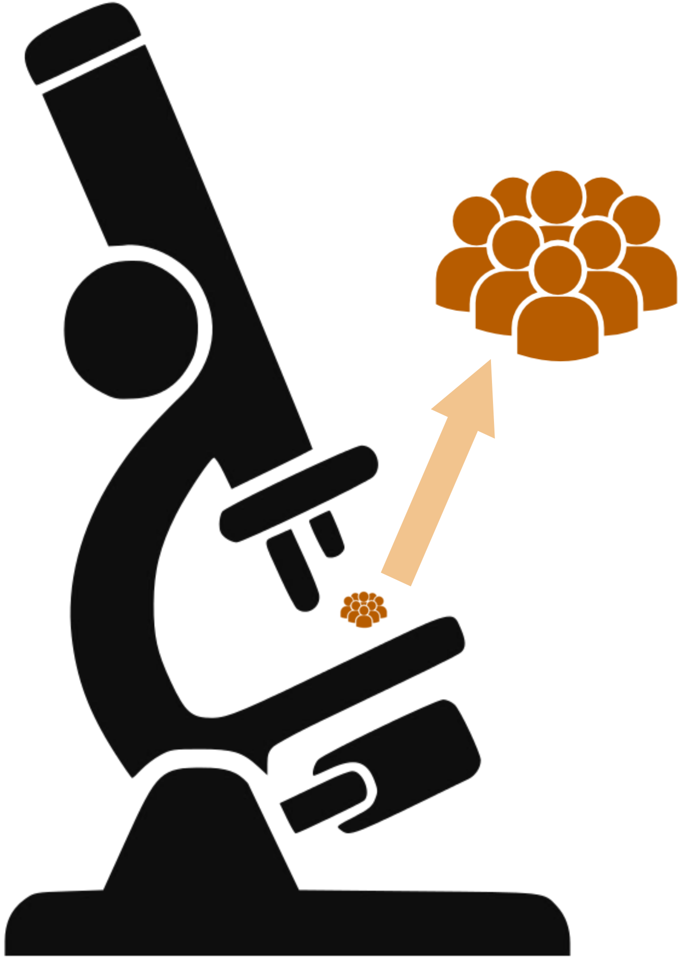
Luca Bruno / AP



2013

NBC NEWS

Michael Sohn / AP



Digital Footprints of Human Activity

VISA
direct
Maestro
DEBIT CARD
VISA

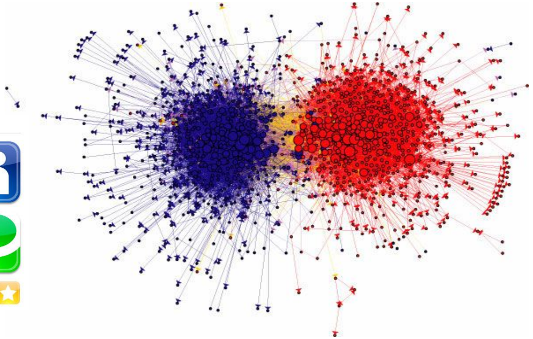
1 25002 74135 0

Shopping patterns

Digital Footprints of Human Activity

Shopping patterns

Social Ties



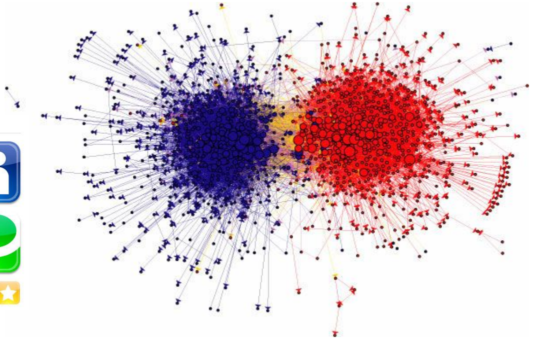
Opinions

WIKIPEDIA
The Free Encyclopedia

Digital Footprints of Human Activity

Shopping patterns

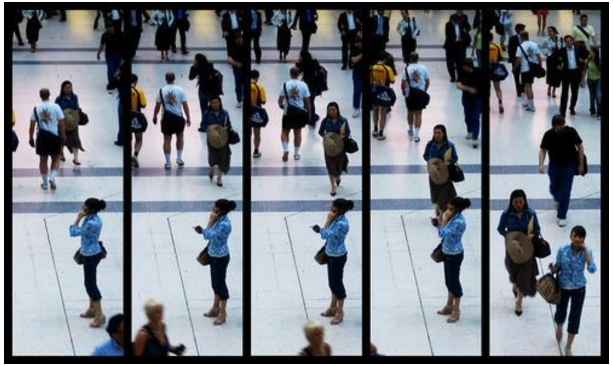
Social Ties



Opinions

WIKIPEDIA
The Free Encyclopedia

Movements



Digital Footprints of Human Activity

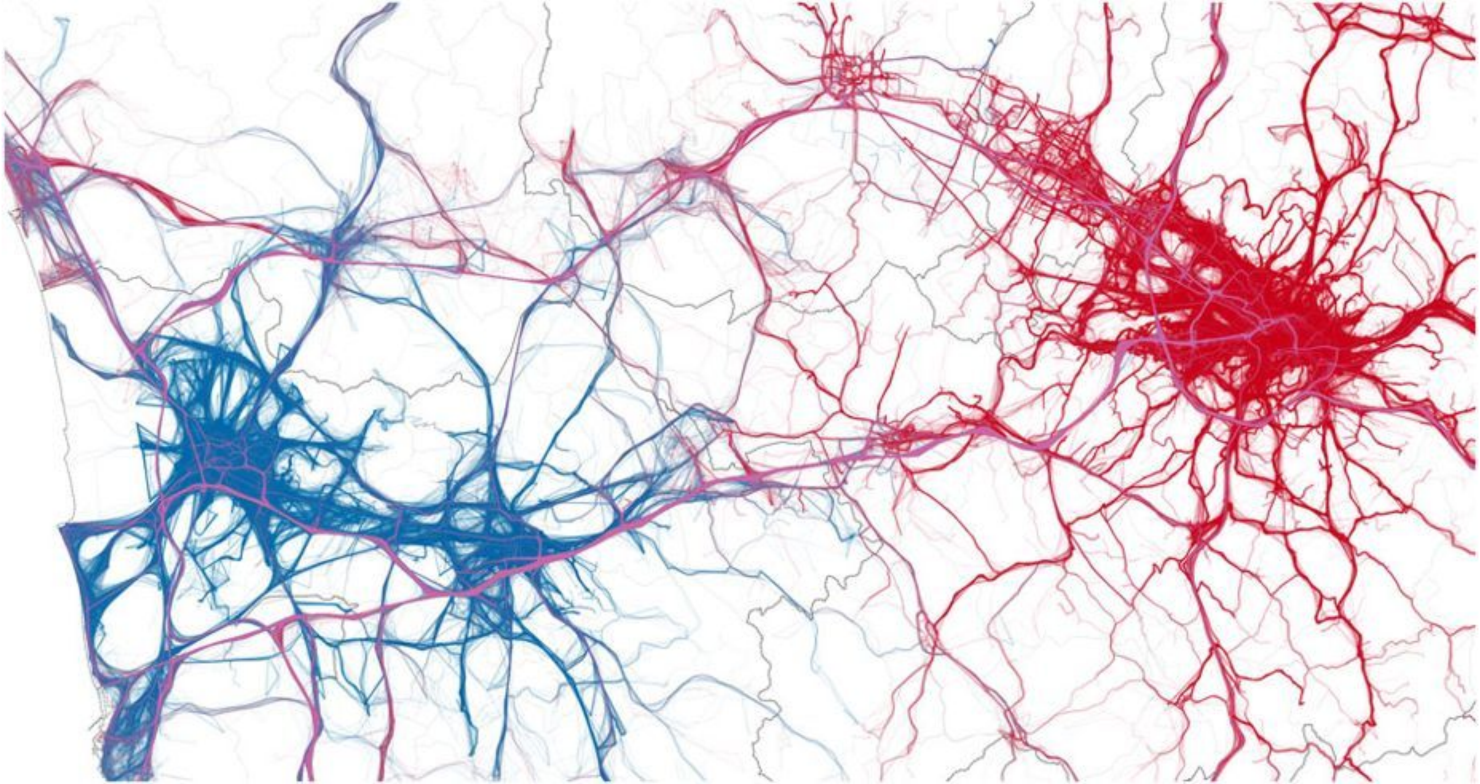
- **Volume**: the incredible amounts of data generated each second

- **Velocity**: speed at which vast amounts of data are being generated, collected and analyzed

- **Variety**: the different types of data we can now use

- **Veracity**: quality or trustworthiness of the data

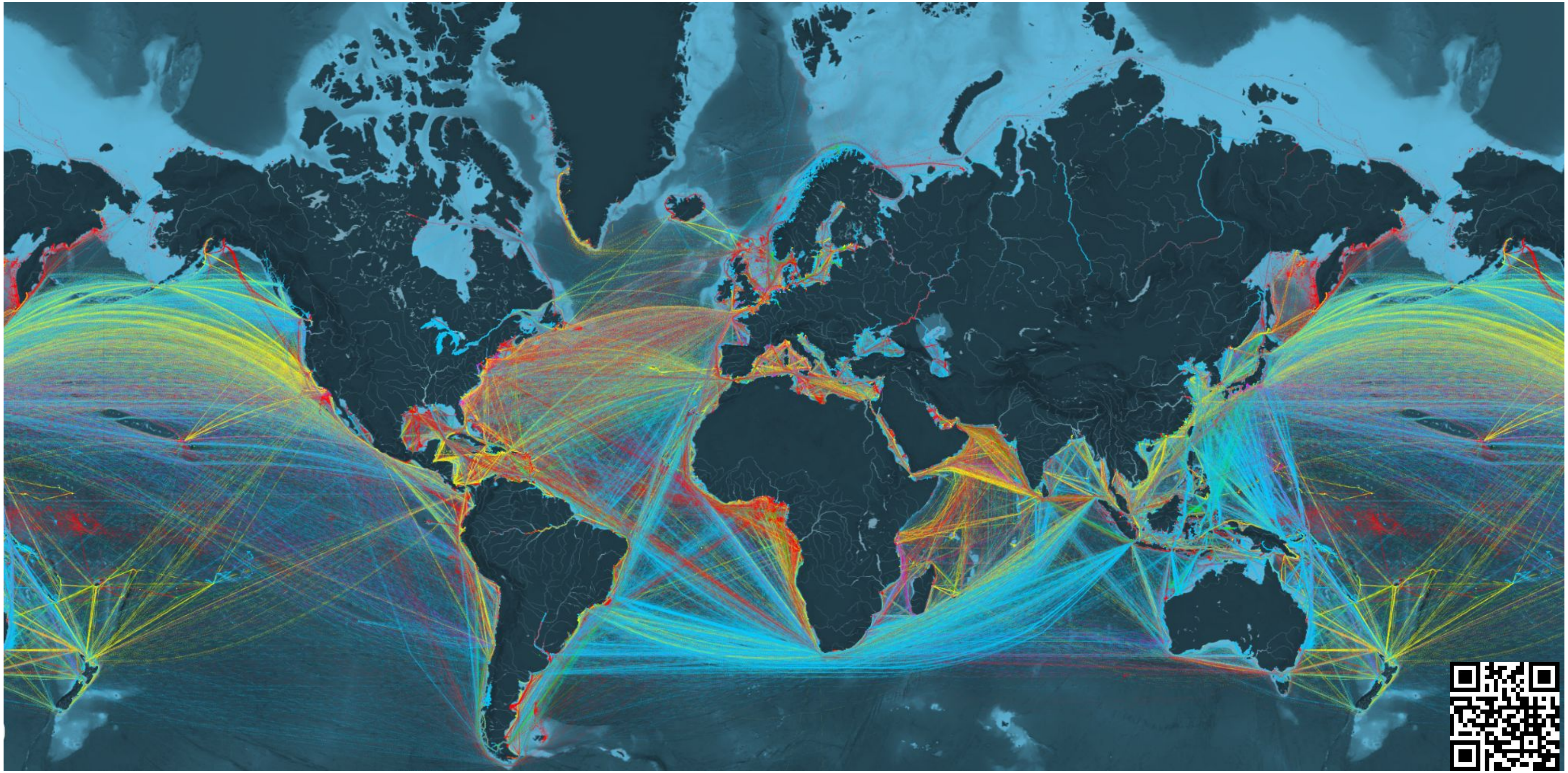
- **Value**: the worth of the data being extracted



Pappalardo et al., Returners and Explorers dichotomy in Human Mobility, Nature Communications 6, 8166 (2015).
https://doi.org/10.1038/ncomms9166

Wembley
Olympic Park
Big Ben
Wimbledon

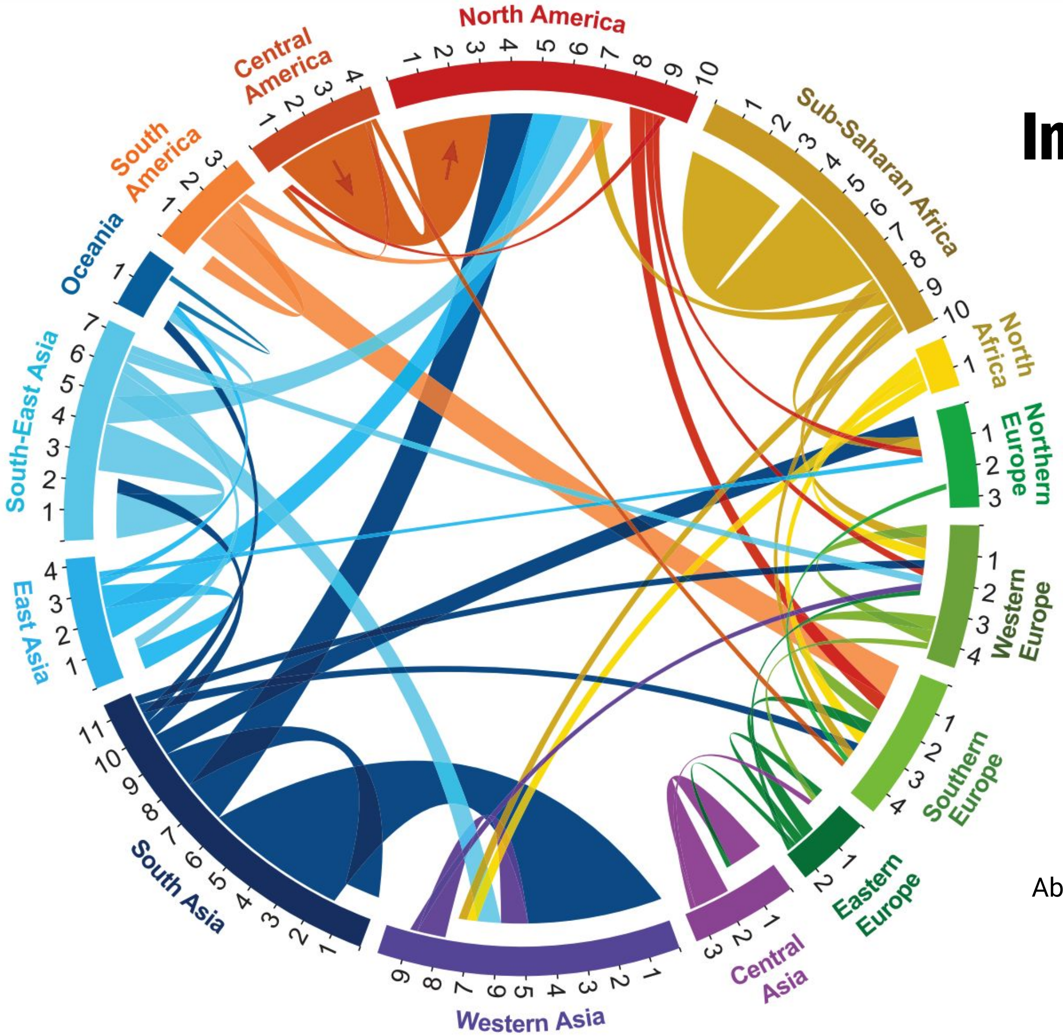
The rest of the city rises and leaves the house to begin a new day.
And our insight around driving behaviour increases second by second, minute by minute.



Ships trajectories: https://www.shipmap.org/

International migration flows

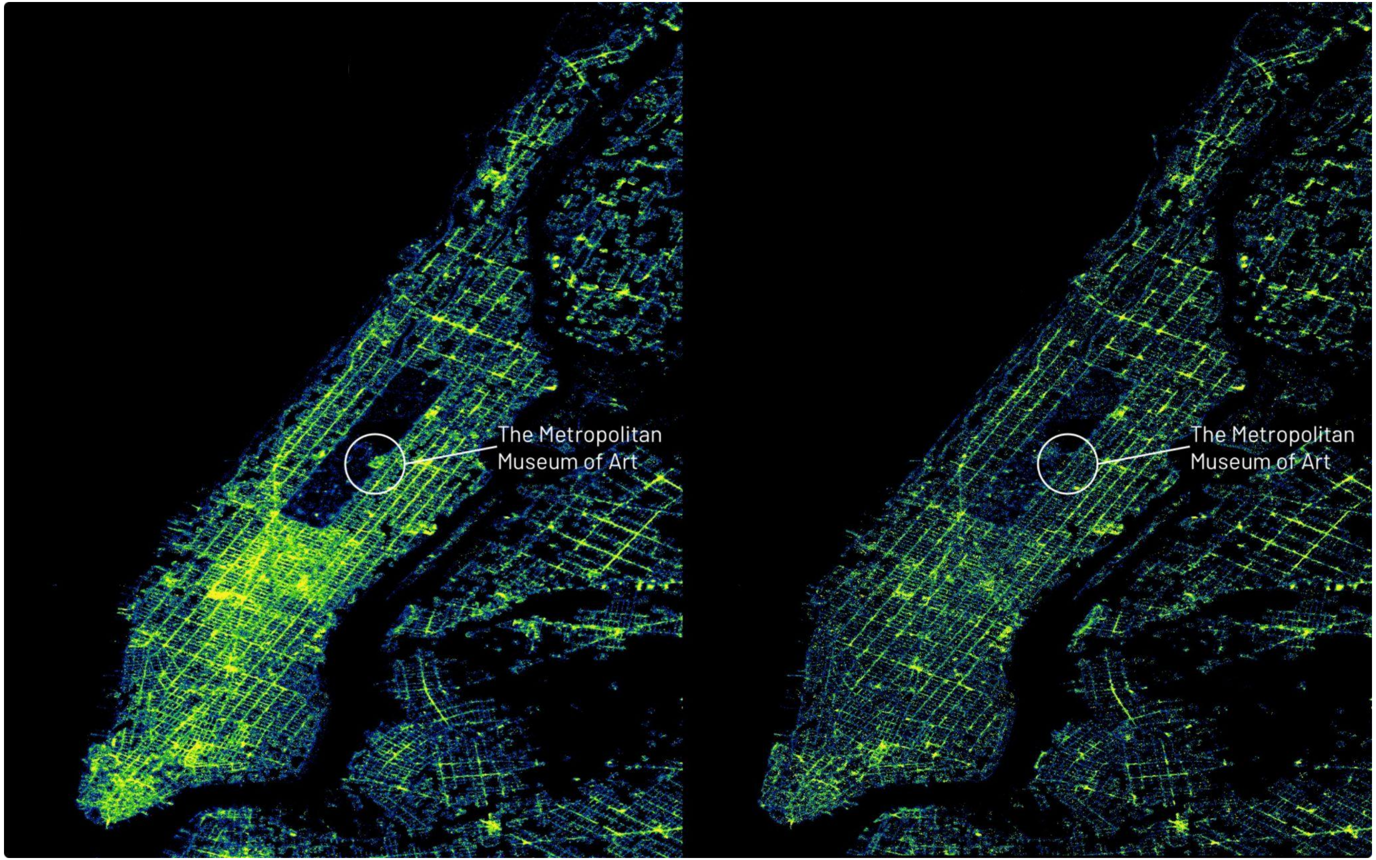
2005-2010

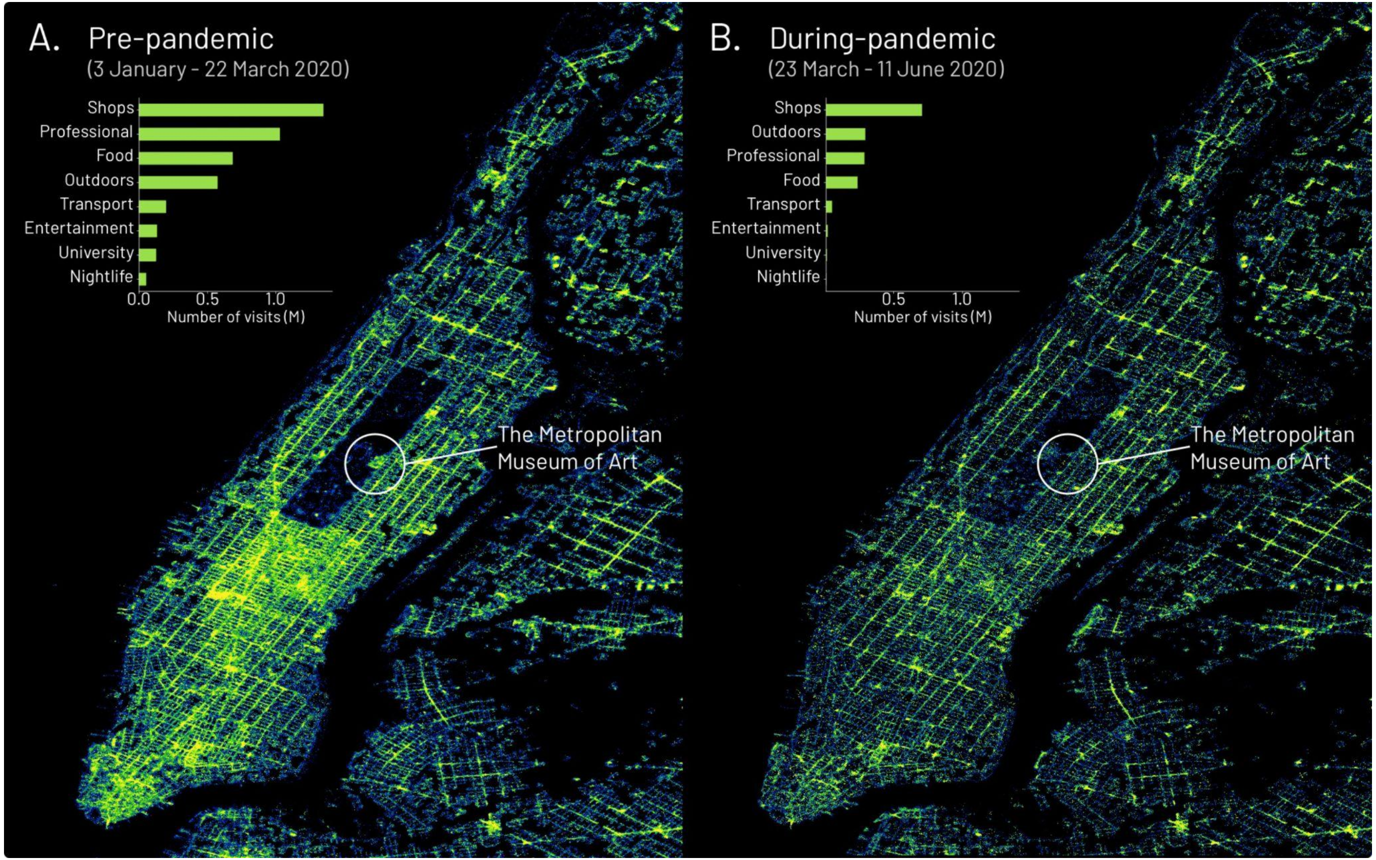


- number of migrants (inflows and outflows) in millions between and within world regions

- (only flows containing at least 170,000 migrants)

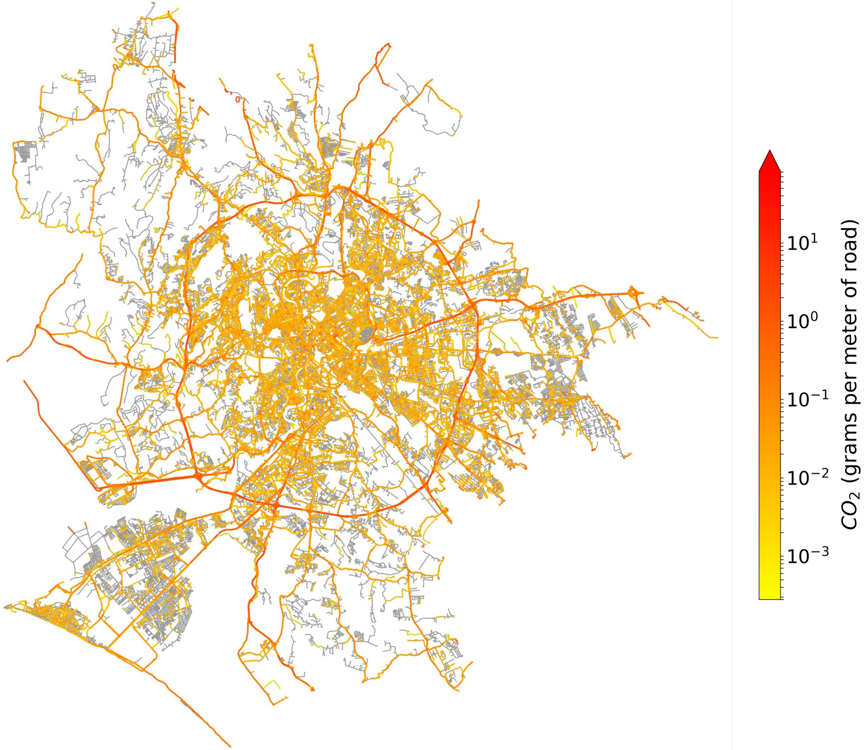
Abel and Sander, Quantifying global international migration flows, Science 343.6178 (2014): 1520-1522.

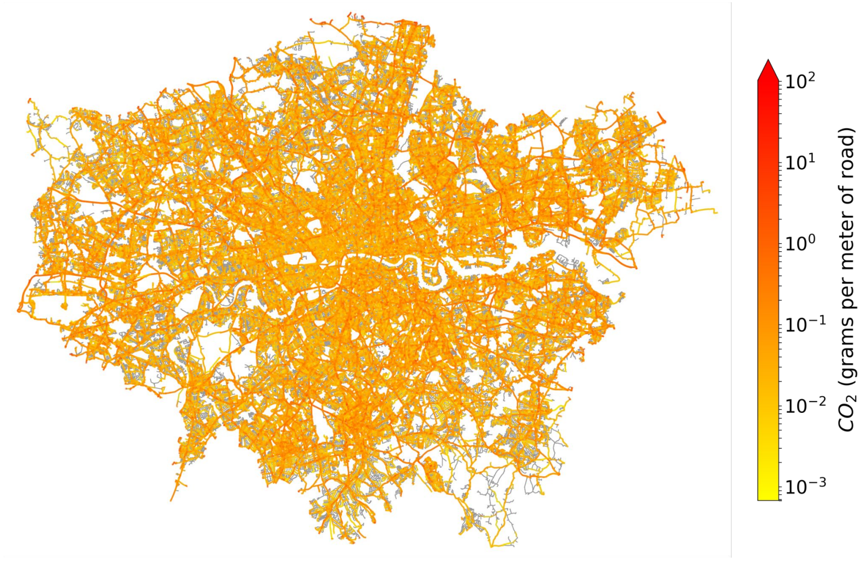

The Metropolitan Museum of Art
The Metropolitan Museum of Art


A. Pre-pandemic
(3 January - 22 March 2020)
Shops
Professional
Food
Outdoors
Transport
Entertainment
University
Nightlife
0.0
0.5
1.0
Number of visits (M)
The Metropolitan Museum of Art
B. During-pandemic
(23 March - 11 June 2020)
Shops
Outdoors
Professional
Food
Transport
Entertainment
University
Nightlife
0.5
1.0
Number of visits (M)
The Metropolitan Museum of Art

Lucchini et al., Living in a pandemic: changes in mobility routines, social activity and adherence to COVID-19 protective measures. Scientific Reports 11, 24452 (2021). https://doi.org/10.1038/s41598-021-04139-1

CO2 emissions on roads


10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
CO_2 (grams per meter of road)


10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
CO_2 (grams per meter of road)

Böhm et al. Gross polluters and vehicle emissions reduction. Nature Sustainability 5, 699–707 (2022).
https://doi.org/10.1038/s41893-022-00903-x

What will you learn in GSA?

Module 1: Spatial and Mobility Data

- Basic concepts
  - Geographic coordinates systems, Vector data model

- Data types
  - Trajectory, Flows, Tessellations

- Spatial and Mobility data
  - Mobile Phone Records, GPS traces, Social media records, POIs, Road Networks

- Preprocessing mobility data
  - Filtering, compression, stop detection, trajectory segmentation, trajectory similarity and clustering

- Practice: open-source tools for geospatial analysis
  - Shapely, GeoPandas, folium, scikit-mobility, osmnx, and more

Module 2: Patterns and Laws

- Spatial analysis
    - point patterns, spatial autocorrelation, GWR
- Individual mobility patterns
- Collective mobility patterns
- Practice: analyze mobility data with scikit-mobility

Module 3: Predictive and Generative Models

- Prediction
  - Next-location prediction
  - Crowd flow prediction
  - Spatial interpolation

- Generation
  - Trajectory generation
  - Flow generation

- Practice: mobility prediction and generation in Python

Module 4: Applications

- Urban Segregation models
- Navigation Principles
- Estimating Pollution

to study for the exam

Material

- [book] Introduction to geographic information systems, Kang-Tsung Chang, McGraw-Hill
    - Chapter 1

- [paper] Human Mobility: Models and Applications, Barbosa et al., Physics Reports
    - Section 1 (Introduction)