Advanced modeling hands-on session:

human mobility modeling

Mattia Mazzoli

July 2 2025, Mahidol University, Bangkok

ISI Foundation

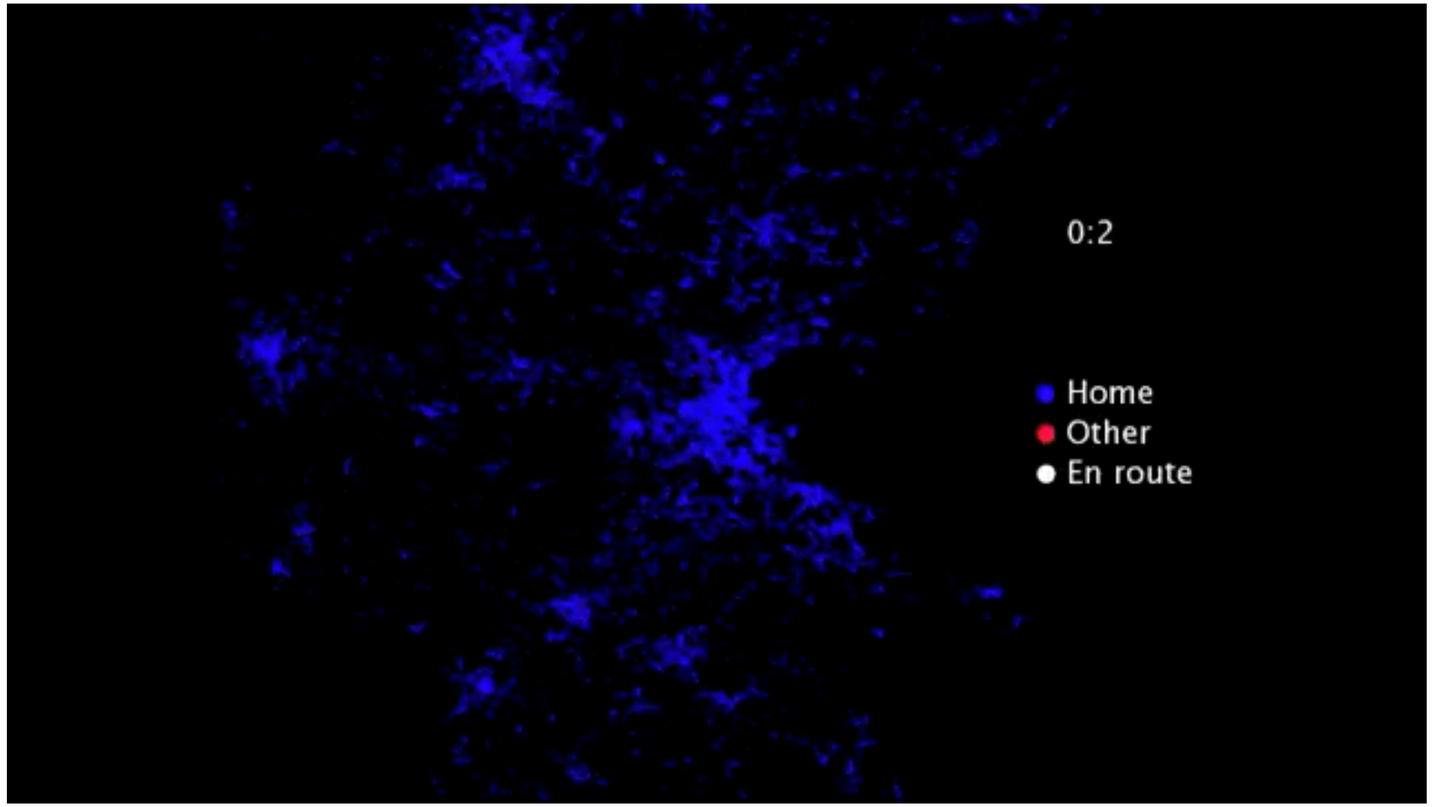
Human mobility modeling

Collective models

- Gravity model
- Radiation model

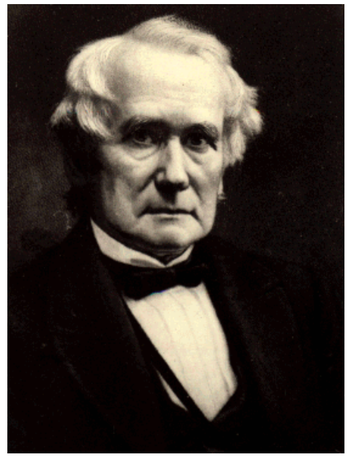
Individual models

- EPR model
- MATsim
- Containers model



Marta Gonzalez, YouTube

Gravity model

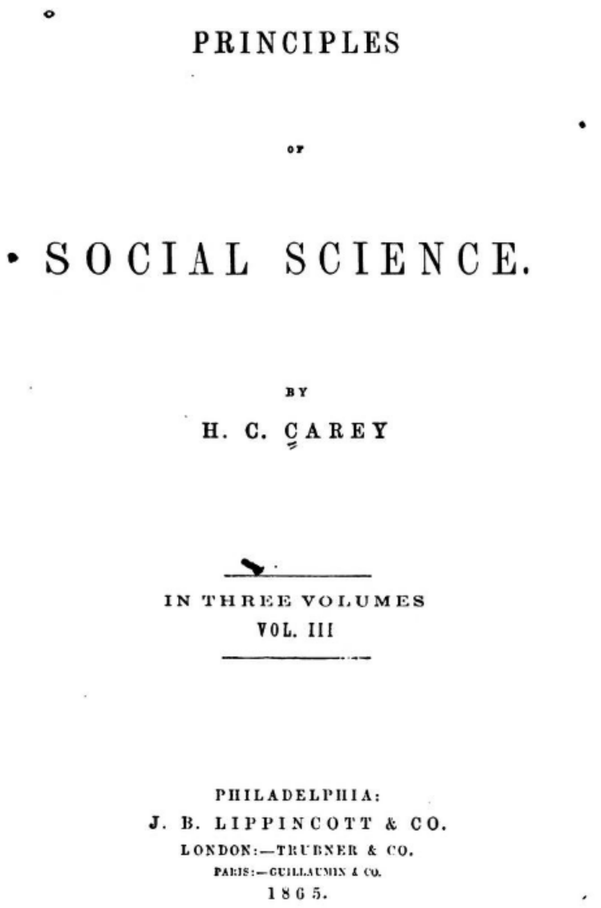


$$\frac{P_i P_j}{D_{ij}}$$

H.C. Carey (1865)
US economist & economic adviser of Abraham Lincoln

"Man tends of necessity to gravitate towards his fellow-man... and the greater the number collected (of man, ndr) in a given space the greater is the attractive force there exerted..."

"Gravitation is here, as everywhere else in the material world, in the direct ratio of the mass, and in the inverse one of the distance"



PRINCIPLES

OF

SOCIAL SCIENCE.

BY

H. C. CAREY

IN THREE VOLUMES
VOL. III

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
LONDON:—TRUBNER & CO.
PARIS:—GUILLAUMIN & CO.
1865.

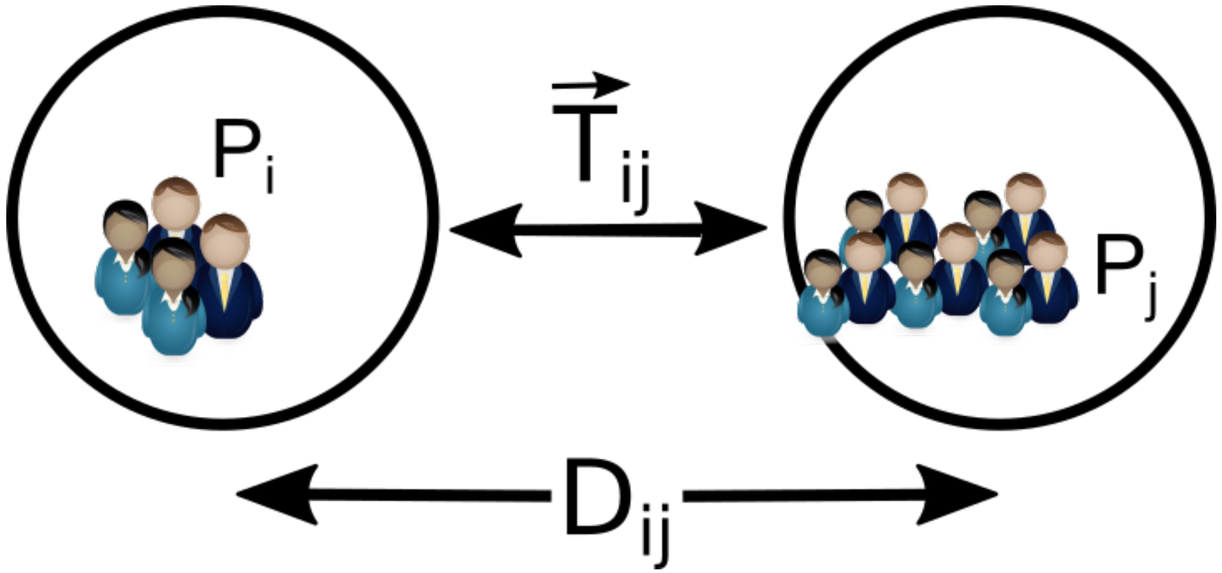
Gravity model

$$T_{ij} \propto \frac{P_i P_j}{D_{ij}}$$

G.K. Zipf (1946)
US linguist and philologist

THE $\frac{P_1 P_2}{D}$ HYPOTHESIS: ON THE INTERCITY MOVEMENT OF PERSONS

GEORGE KINGSLEY ZIPF
Harvard University



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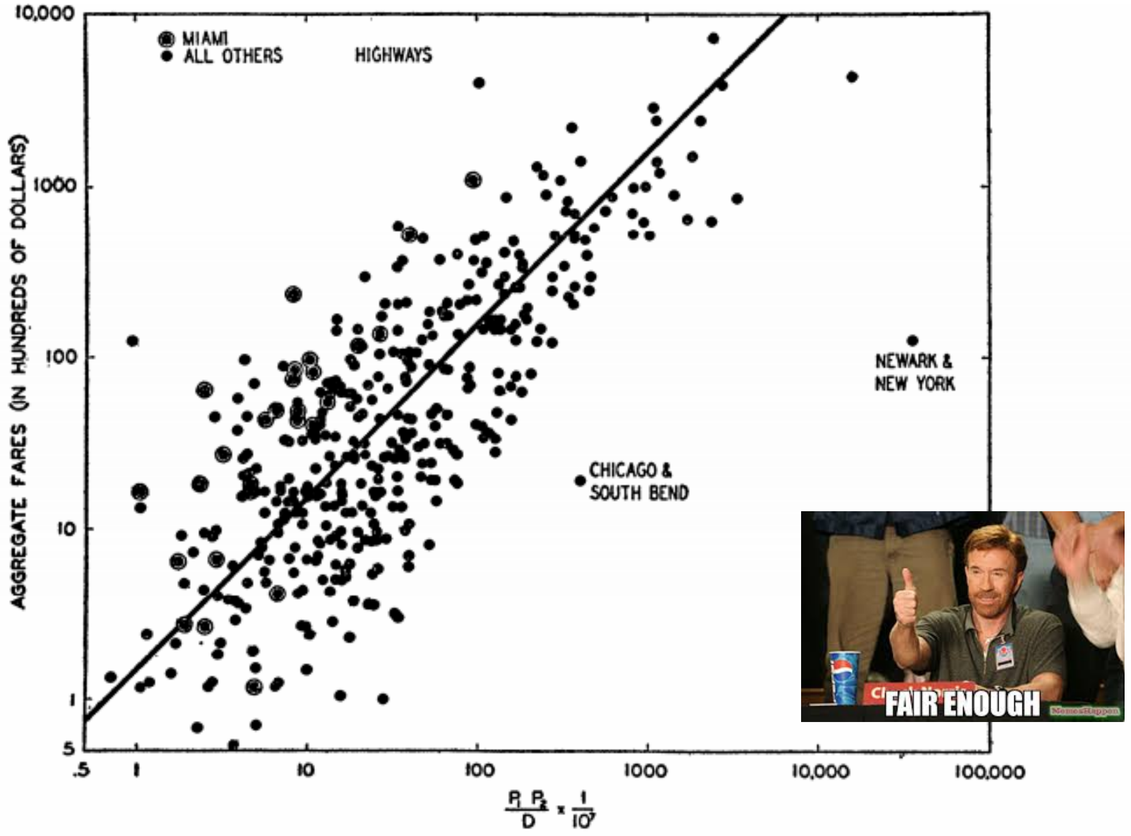


FIGURE 4. The aggregate fares (in hundreds of dollars) paid by the highway passengers reported in Figure 3. The ideal line has a slope of 1.

Gravity model

Unconstrained gravity model $T_{ij} = K m_i m_j f(r_{ij})$ ⟶ deterrence function

- Power law: $r_{ij}^{-\alpha}$
- Exponential $e^{-r_{ij}/d'}$

Singly constrained gravity model
(Production constrained)

$$T_{ij} = K_i O_i m_j f(r_{ij})$$

Doubly constrained gravity model

$$T_{ij} = K_i O_i L_j A_j f(r_{ij})$$

Needs data on outflows and inflows
Unfeasible without mobility data

$$O_i = \sum_j T_{ij}$$

$$A_j = \sum_i T_{ij}$$

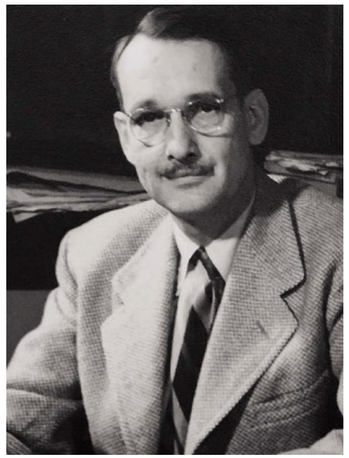
Barbosa, Hugo, et al. "Human mobility: Models and applications." Physics Reports 734 (2018): 1-74.

Radiation model

Meanwhile in Sociology...

Tired of looking at the stars, Professor Jenkins takes up sociology.

Intervening opportunities model



$$\frac{dy}{ds} = \frac{a}{x}\frac{dx}{ds}$$

S.A. Stouffer (1940)
US Sociologist

"The number of persons going a given distance is directly proportional to the number of opportunities at that distance and inversely proportional to the number of intervening opportunities."

American
SOCIOLOGICAL REVIEW

Volume 5 DECEMBER, 1940 Number 6

INTERVENING OPPORTUNITIES: A THEORY RELATING MOBILITY AND DISTANCE*

SAMUEL A. STOUFFER
University of Chicago

Intervening opportunities model

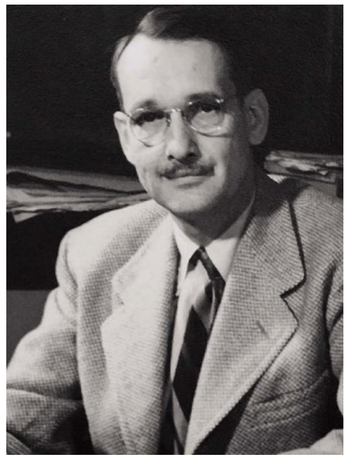


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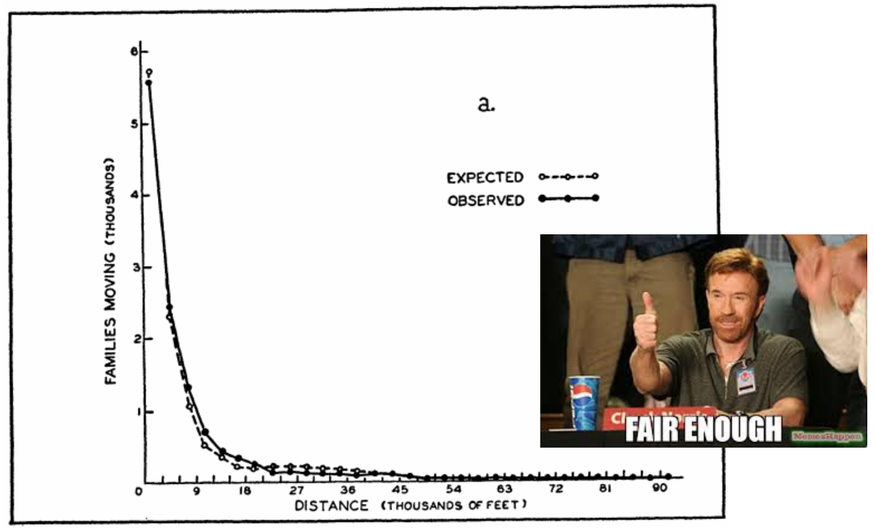
CHART 1. NUMBER OF FAMILIES MOVING FROM LOCATIONS WITHIN TWELVE WHITE CENSUS TRACTS, BY INTERVALS OF DISTANCE. COMPARISON OF EXPECTATION, FROM EQUATION 1, WITH ACTUAL DISTRIBUTION. CLEVELAND, OHIO, 1933–35.[1]



Radiation model

LETTER

doi:10.1038/nature10856

A universal model for mobility and migration patterns

Filippo Simini[1,2,3], Marta C. González[4], Amos Maritan[2] & Albert-László Barabási[1,5,6]

(2012)

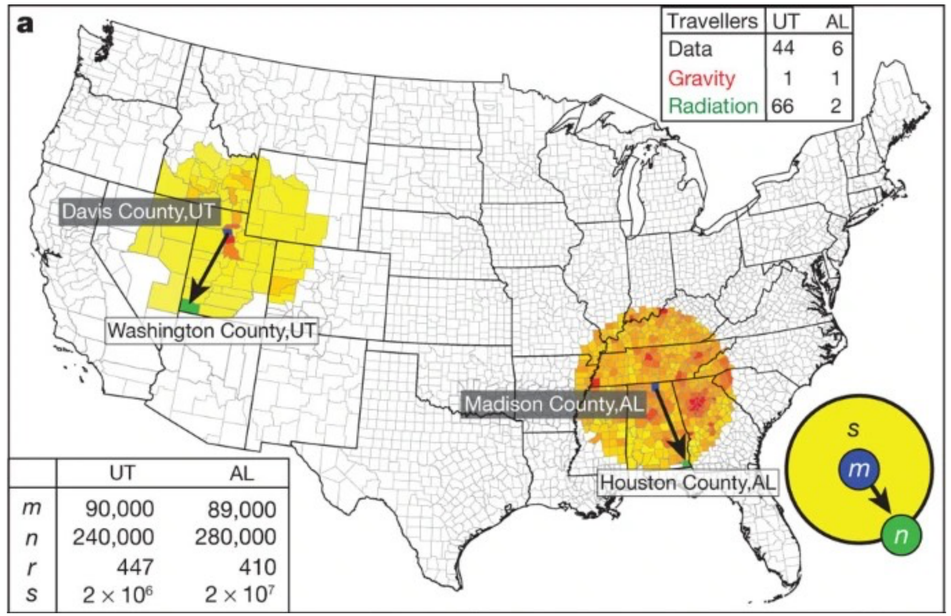
Inspired by the Intervening opportunities model

It mimics the radiation and absorption of particles
Particles emitted and absorbed proportional to local population

Opportunities = individuals

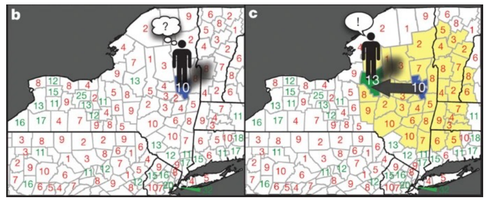
Parameter free

Requires knowledge on the outflows



$$T_{ij} = T_i \frac{P_i P_j}{(P_i + s_{ij})(Pi + P_j + s_{ij})}$$

$$T_i = \sum_j T_{ij}$$



Simini, Filippo, et al. "A universal model for mobility and migration patterns." *Nature* 484.7392 (2012): 96-100.
Barbosa, Hugo, et al. "Human mobility: Models and applications." Physics Reports 734 (2018): 1-74.

Hands on mobility models

Let’s try gravity and radiation models on real data

Hands on session
Go to https://github.com/mattiamazzoli/workshop/
Click on *metapop*

Notebook:
Open the *mobility modeling.ipynb* notebook