Cities, Mobility & Complexity in a Post-Pandemic World

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MIT Mobility Forum
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MOBILITY IS A MEANS TO A GREEN, JUST, PROSPEROUS WORLD FUTURE
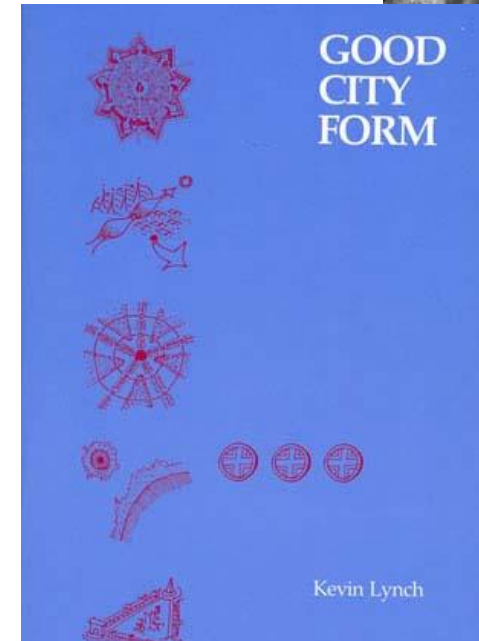
Presentation Outline

- Cities as complex systems.

- Cities & Transport.

- Disruption:
  - COVID-19 pandemic.
  - Urban informatics.

- Implications for change & future sustainability.

Standing on the shoulders of giants.
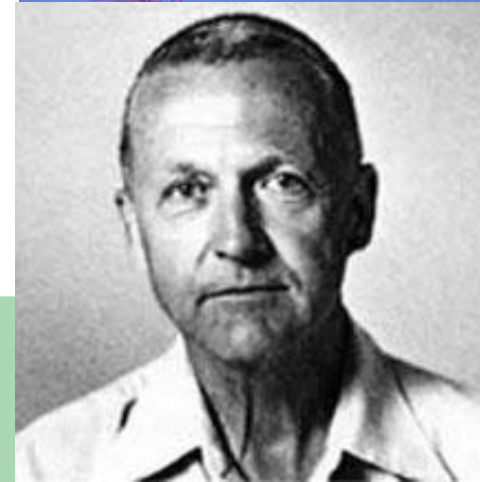
Cities are systems of systems

- Cities are complicated systems of interacting systems:
  - Economic.
  - Social.
  - Political.
  - Health.
  - Technical:
    - Transportation.
    - Information.
    - Energy.
    - ...
- They are embedded within even more complex biological & physical worlds.

Physical (non-biological) world

Biological world (living ecosystem)
(includes COVID-19!)

Human Systems

Political
(power, "taking")

Social

Economic
(money, "trading")

Technological
(applying energy)

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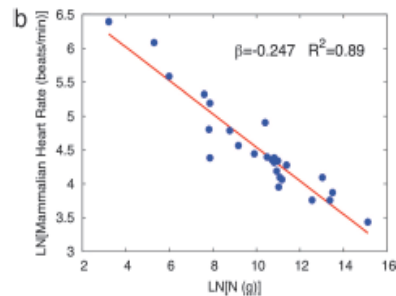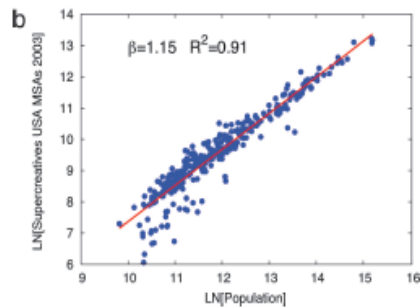*(Bettencourt, 2013)*

Fig. 1. Examples of scaling relationships. (a) Total wages per MSA in 2004 for the U.S. (blue points) vs. metropolitan population. (b) Supercreative employment per MSA in 2003, for the U.S. (blue points) vs. metropolitan population. Best-fit scaling relations are shown as solid lines.

Fig. 2. The pace of urban life increases with city size in contrast to the pace of biological life, which decreases with organism size. (a) Scaling of walking speed vs. population for cities around the world. (b) Heart rate vs. the size (mass) of organisms.

They are also social networks:

- Cities are massive social networks, generating myriads of interactions (economic, social, cultural, political, …).
- The bigger the city, the more potential interactions there can be.
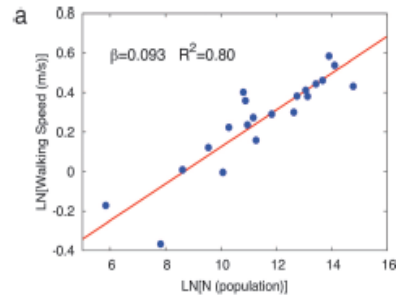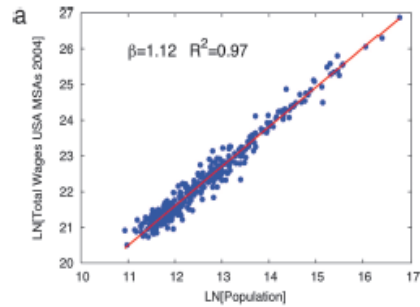- These grow non-linearly with city size & generate agglomeration economies (scaling).

*(Bettencourt, et al. 2007)*

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Transport & Cities

Throughout history the location, size, shape and economic & social functioning of cities has been fundamentally influenced by transportation technology, infrastructure and services.

Transportation networks literally give spatial definition to land and, by making the land *accessible,* they make it useful.
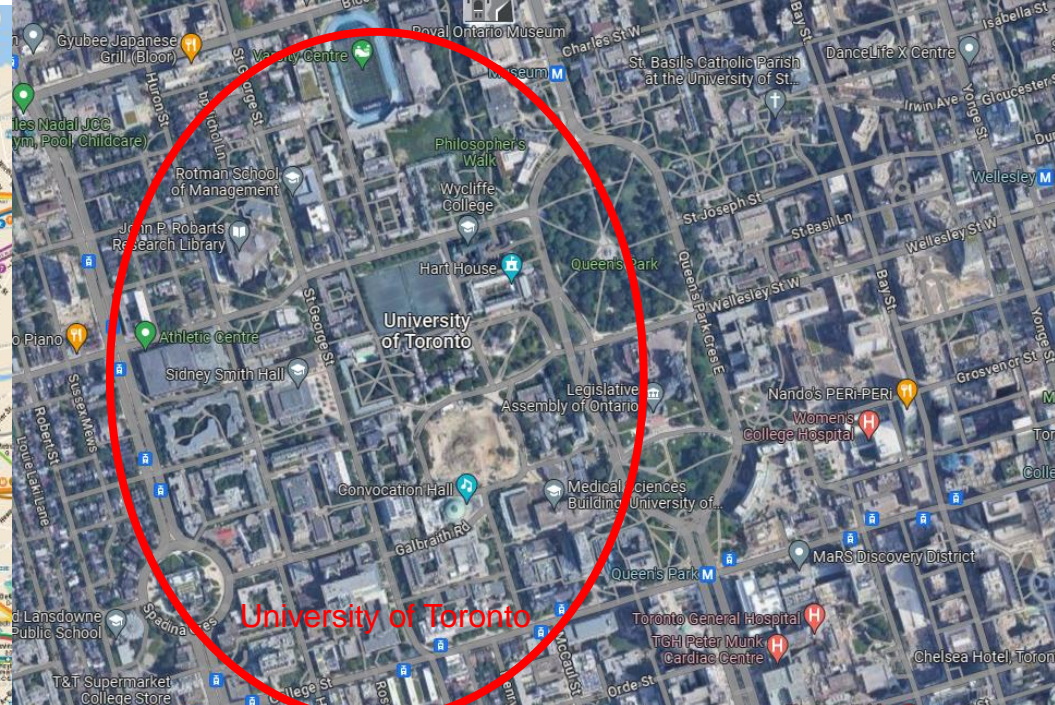
System of Systems (1): The Urban Activity and Transport Systems

- The transportation system "mediates" between all activities in space, influencing land development, the location choices of households, firms & other activities.

- The distribution of people, businesses & activities, in turn, drives the demand for transportation.

- "Transportation 101"

Manheim, M.L. (1978)
Fundamentals of Transportation Systems Analysis Volume 1: Basic Concepts, MIT Press

URBAN ACTIVITY SYSTEM

- Land Development
- Location Choice
- Activity Schedules
- Activity Patterns

TRANSPORTATION SYSTEM

- Transportation Network
- Automobile Ownership
- Travel Demand
- Network Flows
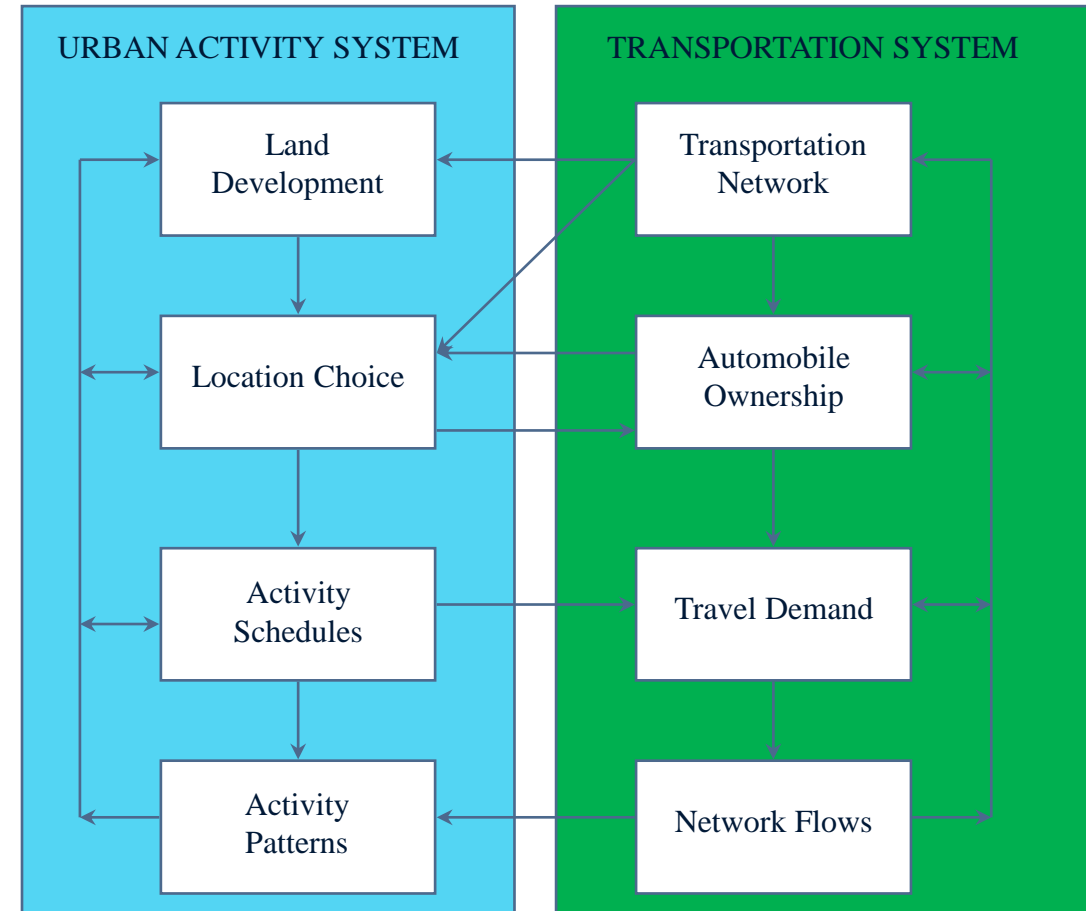
(Meyer & Miller, 1984, 2001, 2013)

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Pre-Industrial Cities
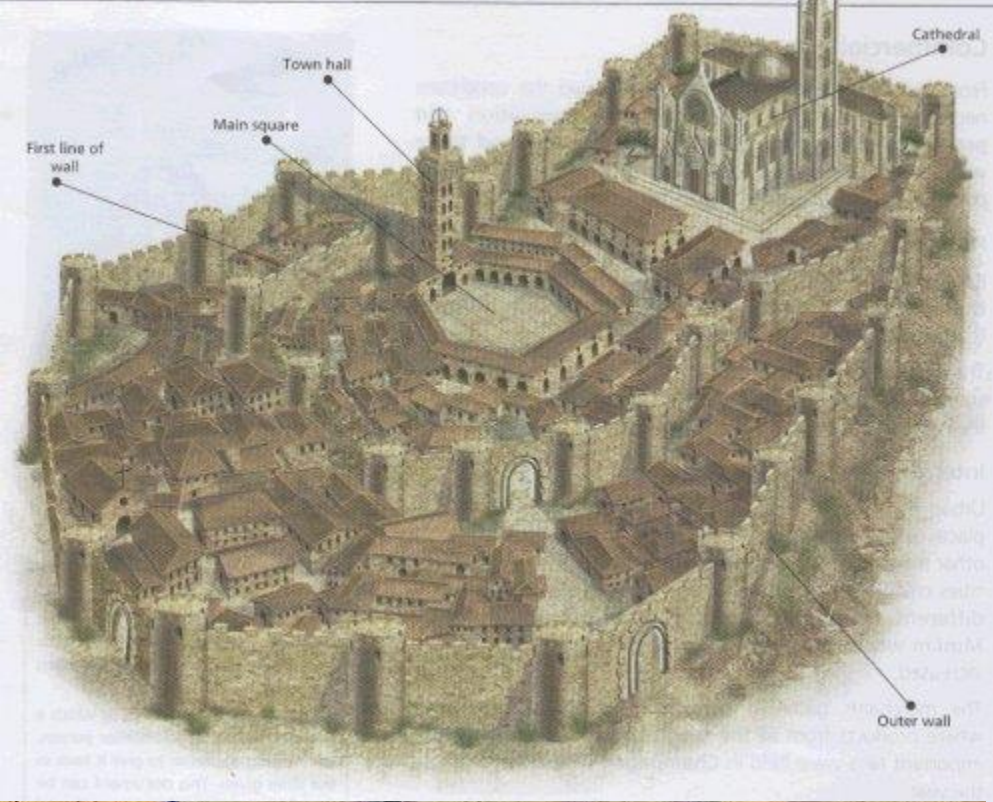
- Pre-industrial cities were small, dense and extremely compact.
- Walking and animal-powered vehicles were the only options for intra-city travel.
- Wind and animal-powered transport were the only inter-city options:
- Largely a person-based (individual) supply of transportation (other than the roads/streets).

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Transport Revolution 1: Mechanized ("Industrial") Transport

YEAR 1890

FIG. 55.—The "Rocket," 1829.

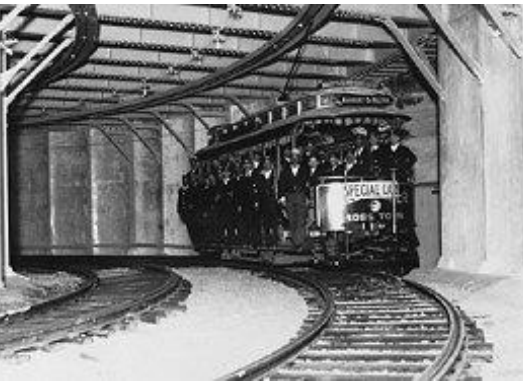- With the Industrial Revolution steam engines and, later, electrically-powered vehicles made mechanized transport possible for the first time, providing <u>much</u> higher-speed and higher-capacity transport services.

- This permitted the size of cities to expand dramatically, leading to:
  - Lower (but by modern standards still high) densities.
  - Vastly larger cities.
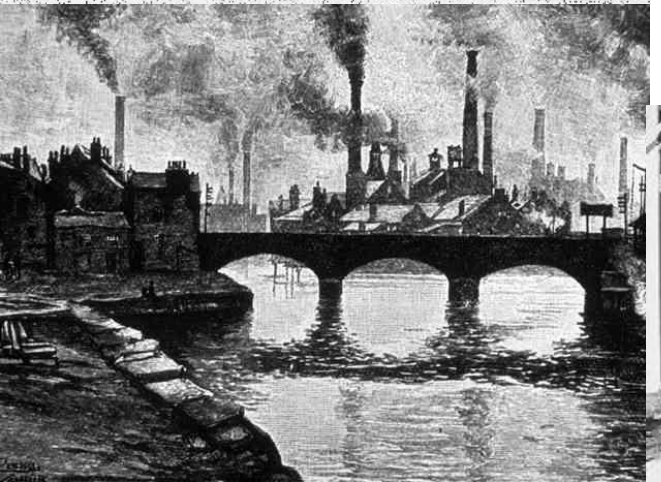
Transport Revolution 2: The Automobile Era

- Started in the early 20ᵗʰ Century, but not having full impact until after WWII.

- Much higher speeds, flexibility of use and its provision of an affordable <u>personal</u> means of transportation, the auto again revolutionized transportation by "freeing":

    - People from fixed-service public transit.
    - Urban development to further spread out ("sprawl") in a dramatically increased, indeed explosive, way.

System of Systems (2): Urban Activity & ICT

- But telecommunications also network people & activities together.
- There has always been a complex complementary/competitive (but, overall, synergistic) interaction between travel & communications.
- The pandemic has massively disrupted & accelerated this interaction.

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Attractors

The Lorenz Attractor
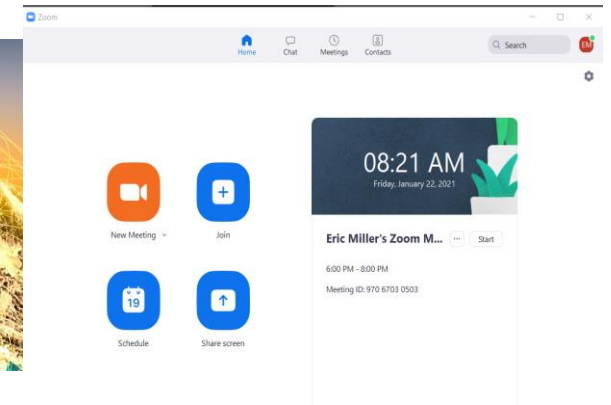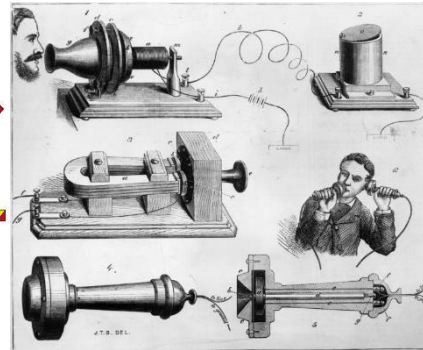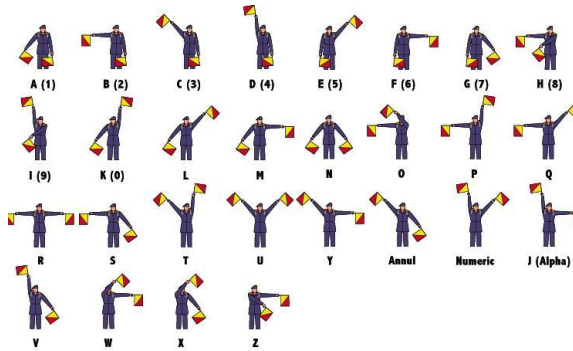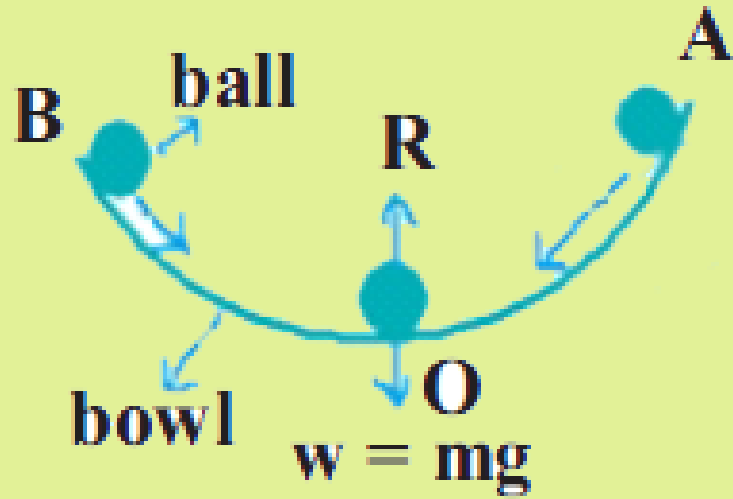
- Every system has one or more attractors, to which the system state will tend to converge (if left undisturbed).
- Attractors are an emergent characteristic of the system.
- The number & location of the attractor(s) depends largely on the system structure, in particular, its feedback loops.
- Once established, an attractor can be difficult to "break free from".

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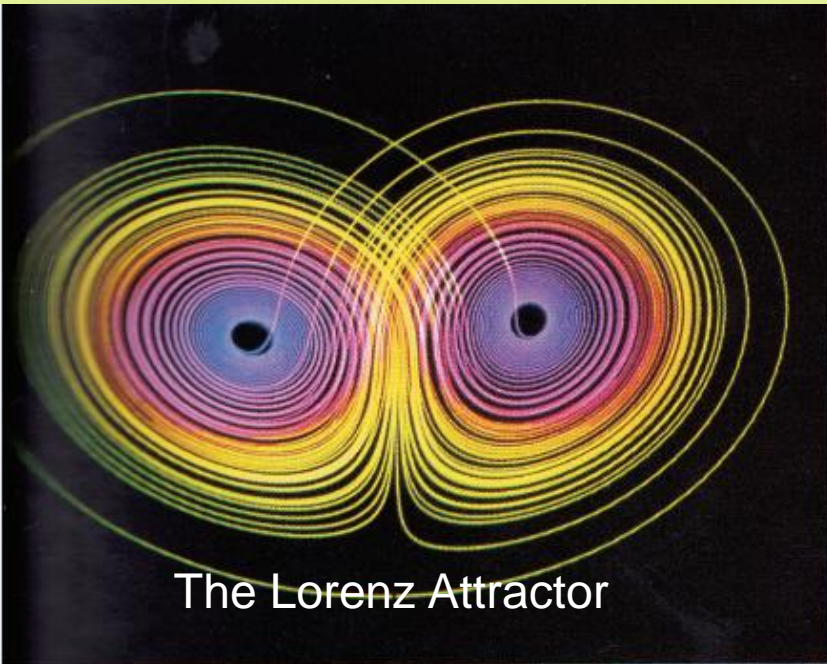
Urban Attractors (1): Pre-Industrial & Transit Cities

- Both the pre-industrial & transit (industrial) cities' "attractor" is one of centralization & concentration of activities & travel flows.
  - Central places (Christaller; Losch).
  - Monocentric cities (Alonso).
  - Radial transit networks.
  - Intensive & mixed use of land.
  - Walkability.
  - Trip length minimization.
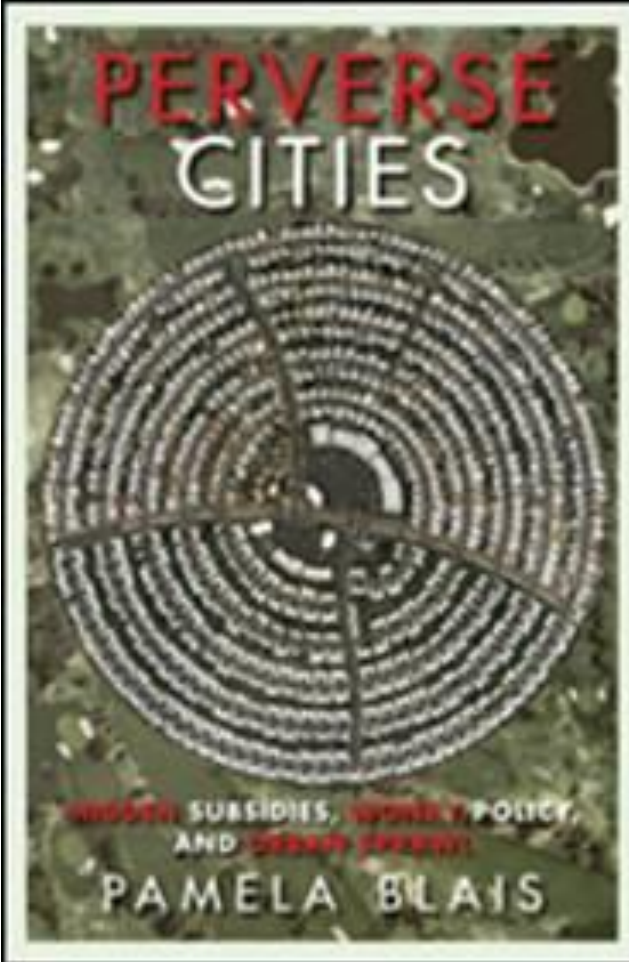
Urban Attractors (2): The Automobile City

- Low-density, dispersed population & activities.

- Extensive (often single-) use of land.

- Grid networks; many-to-many travel flows.

- "Edge Cities" (Garrow).

- Car-dependency; very limited walkability (*Suburban Nation*).

- Mobility maximization.

Urban Attractors (3)

- Both attractors exist within our cities, "competing" with one another.

- Relative "dominance" varies from city to city & country to country, but the auto-centric attractor dominates in most cases (especially in North America).

- Both support the "city as social network" paradigm, but often in very different ways.

Disruption!
A third revolution?
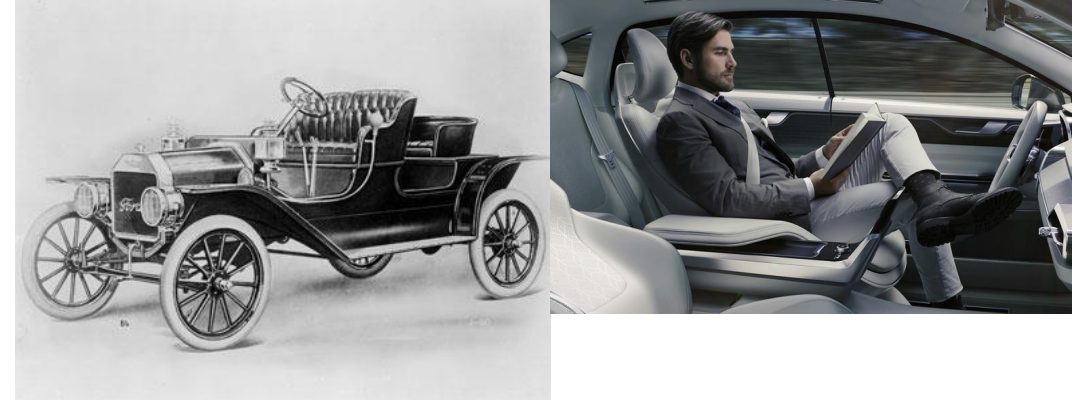
- The transportation system was undergoing significant & numerous technology-based disruptions pre-COVID and will continue to be shaped by these post-COVID.

- And then came COVID-19, the biggest public health crisis in a century, which disrupted our economy and our daily lives in multiple & still-unfolding ways.

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Major Disruptions

1. New technologies & services.
2. ICT, IoT, AI, Big Data.
3. Climate change.
4. Quest for social & economic equity.
5. Global urbanization.
6. COVID-19

Santiago, Chile, 2019

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Santiago, Chile, 2019

$$h_2$$

$$W_2$$

$$h_1$$

$$W_1$$

$$v$$

Challenging the status quo.
"Business as usual" simply will not do.
Driving the need for substantive change.
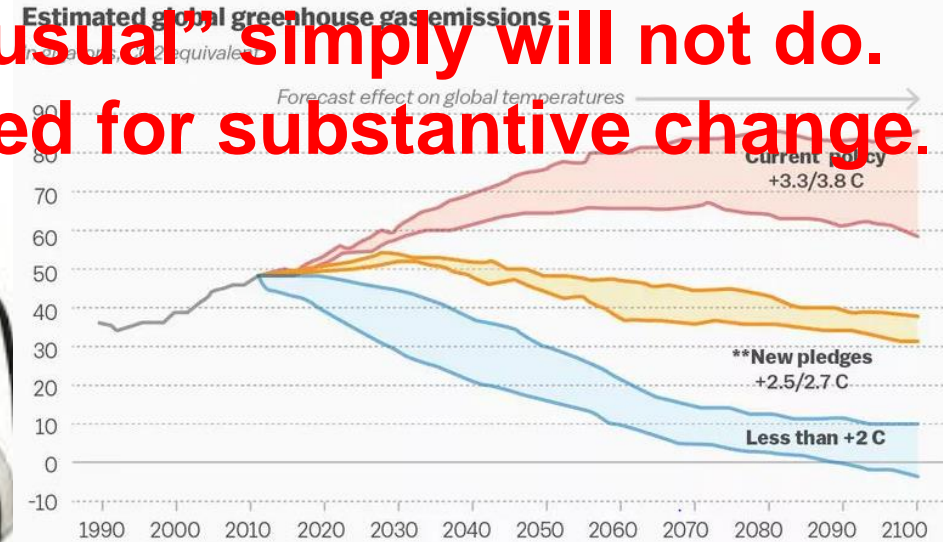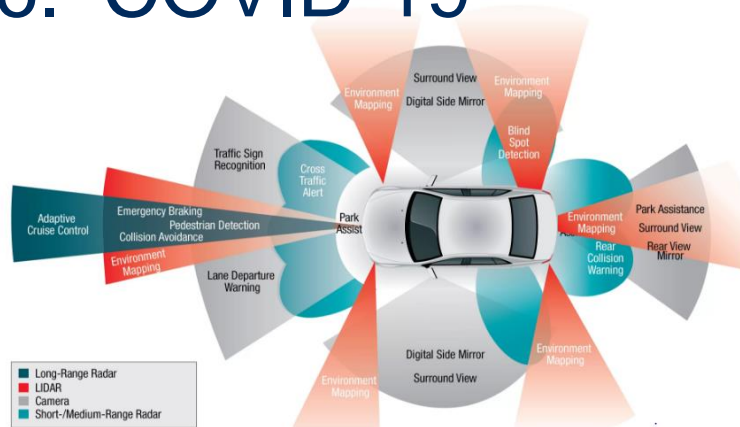
Estimated global greenhouse gas emissions

Forecast effect on global temperatures

Current policy +3.3/3.8 C

**New pledges +2.5/2.7 C

Less than +2 C

*Expected temperature change by 2100, versus period before Industrial Revolution
** Based on intended nationally determined contributions submitted to UNFCCC by Oct. 1
SOURCE: Climate Action Tracker

Vox

Long-Range Radar
LIDAR
Camera
Short-/Medium-Range Radar

Disruptions: COVID-19 & Cities

- COVID-19 has been a "direct attack" on the whole *raison d'etre* of cities:
  - To bring people together to interact.
  - To create massive positive feedback loops (social networks) generating both economies of scale and agglomeration.
  - To be "the containers of civilization" (Mumford, 1961).
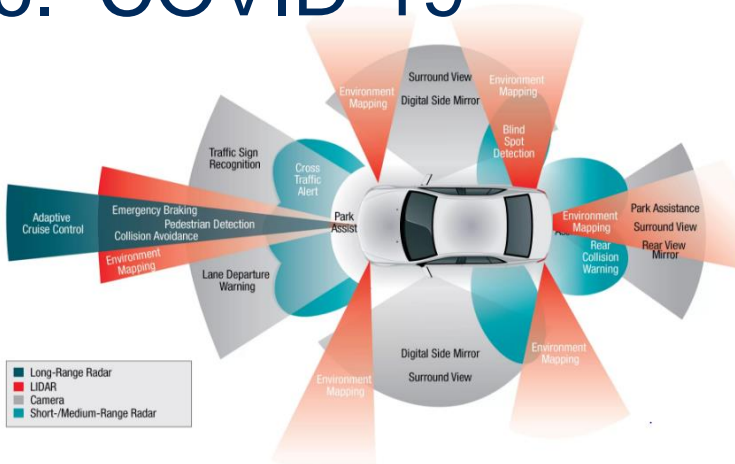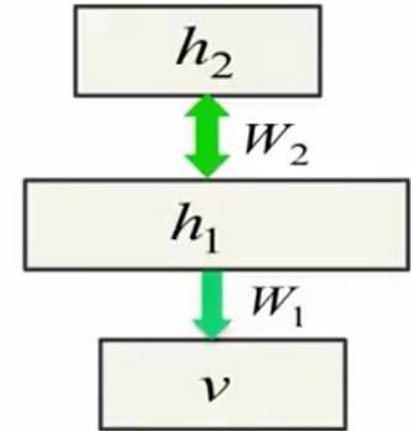

COVID-19

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Major Disruptions

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2. ICT, IoT, AI, Big Data.
3. Climate change.
4. Quest for social & economic equity.
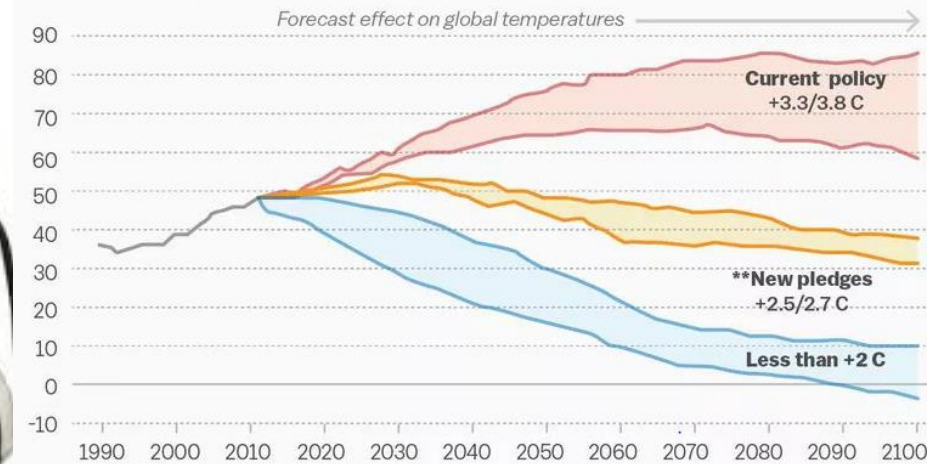5. Global urbanization.
6. COVID-19

Santiago, Chile, 2019

Pathways to change?

h_2

W_2

h_1

W_1

v

Estimated global greenhouse gas emissions

In gigatons, CO2 equivalent

Forecast effect on global temperatures

Current policy +3.3/3.8 C

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Less than +2 C

*Expected temperature change by 2100, versus period before Industrial Revolution
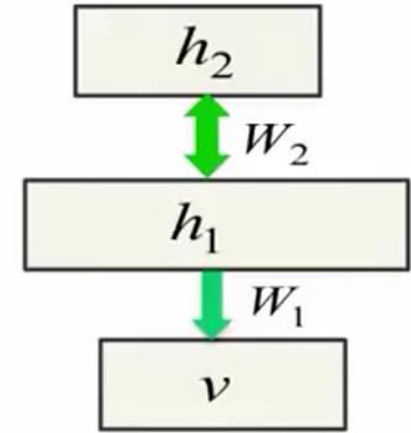** Based on intended nationally determined contributions submitted to UNFCCC by Oct. 1
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Long-Range Radar
LIDAR
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Short-/Medium-Range Radar
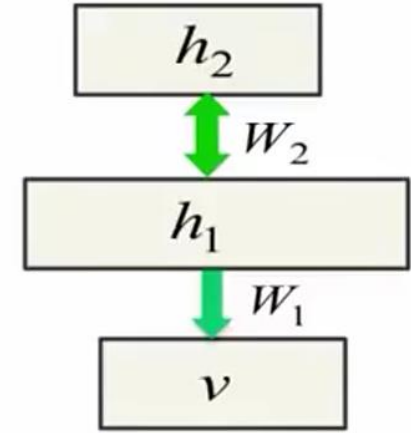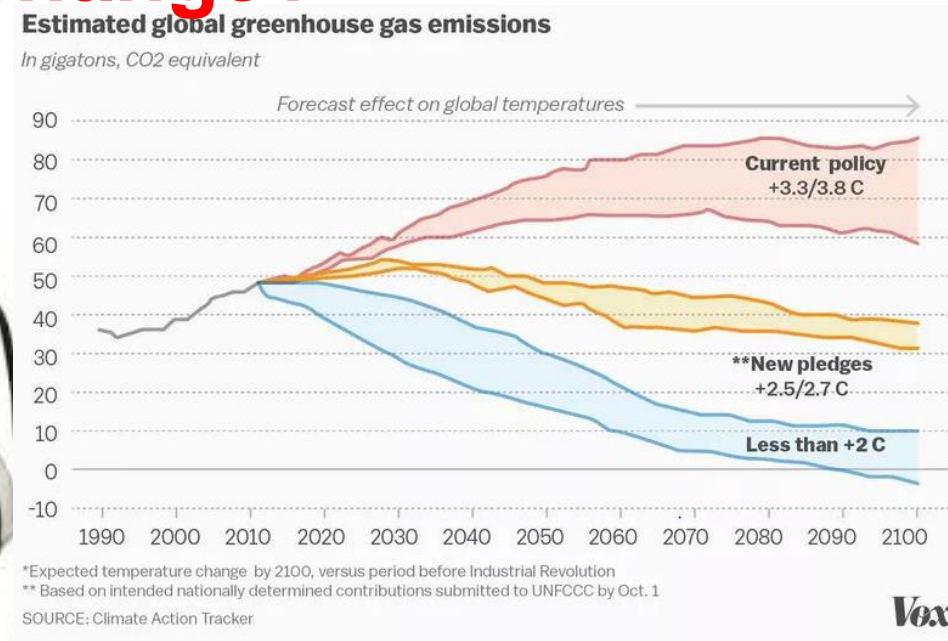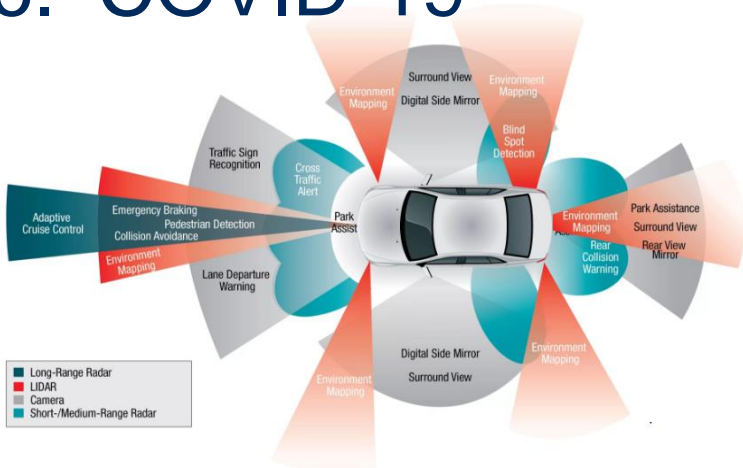
Urban Informatics: A brave new world. Solutions or new problems?

- Urban informatics technology (data, computing, analytics, technology, services) is changing:
  - New mobility technologies & services.
  - Transportation system behaviour:
    - System management & performance (supply).
    - Travel behaviour (demand).
  - Our ability to observe & understand urban systems.
- The pandemic rapidly accelerated many of these impacts.

New technologies & services

V2V
VEHICLE-TO-VEHICLE

V2I
VEHICLE-TO-INFRASTRUCTURE

V2X
VEHICLE-TO-X

- Long-Range Radar
- LIDAR
- Camera
- Short-/Medium-Range Radar
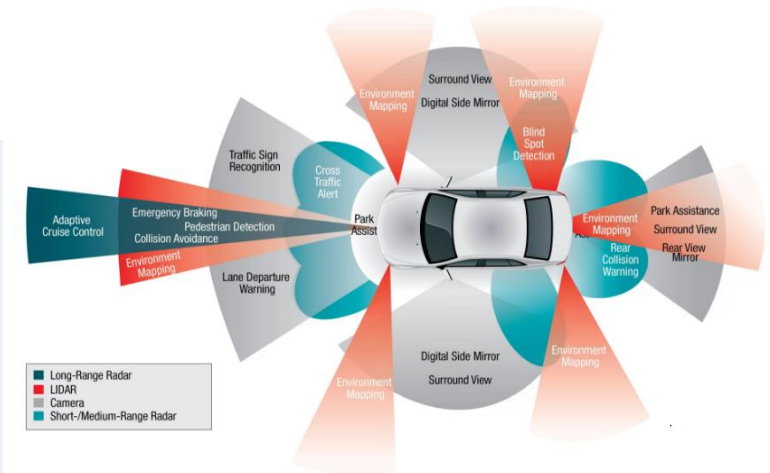
- Connected
- Autonomous
- Electric

UTTRI
Research Report

THE STATE OF DEMAND-RESPONSIVE TRANSIT IN CANADA
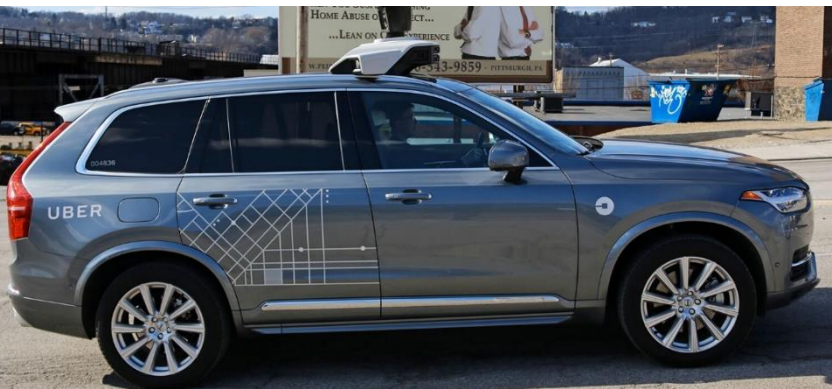
Willem Klumpenhouwer
July 2020

Transportation System Control & Performance

- Real-time network operational control.
- Road pricing.
- Parking control.
- Transit priority.
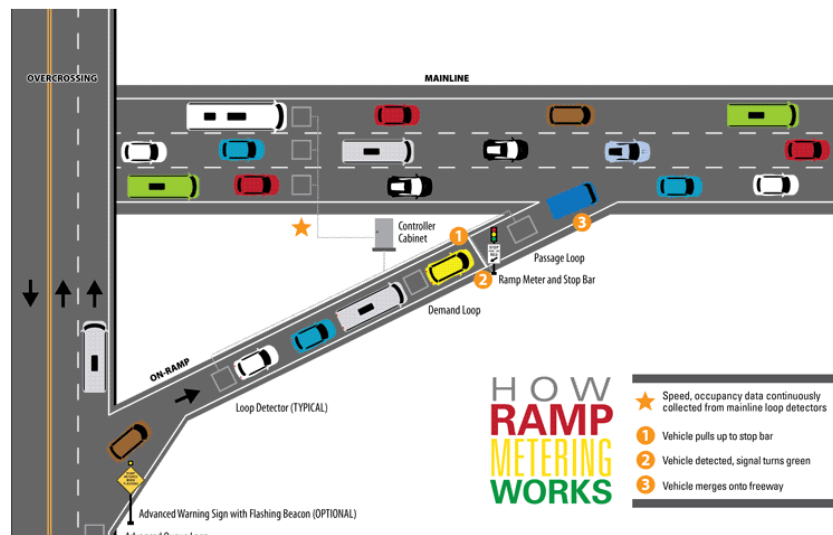
Informatics & Travel Behaviour

- New IT technology (data, computing, software, platforms) having a pervasive effect on travel behaviour.

- The pandemic as accelerated many trends & broken old ways of doing things – i.e., it has been truly disruptive.

- IT impacts include:
    - Real-time information impacts.
    - Activity location choice.
    - Trip generation.
    - Residential location.
    - Auto ownership.
    - EV impacts:
        - Charging/range issues & impacts on travel patterns.
    - CAV impacts: who knows?

A Third Revolution? Shifting Attractors? (1)

- Most technology-based "innovations" are, at best, neutral, and, often, reinforcing wrt attractors:
  - Most mobility services (currently at least) reinforce auto-centric travel at the expense of transit & active travel.
  - Route guidance apps, etc. may make current systems somewhat more efficient, but do not change basic behaviour.
  - Real-time traffic control "efficiencies" reinforce auto-centric travel.
  - Transit control lagging in many cases.

A Third Revolution? Shifting Attractors? (2)

- The pandemic has fundamentally altered the home-work commuting relationship.

- How this "new normal" will stabilize remains to be seen.

- It may, however, reinforce more dispersed settlement patterns, to the detriment of traditional central places.
  - Implications for travel (especially transit)
  - Implications for the functioning of urban economies / social networks?

- May not "change the attractor" but is providing scope for continuing growth of urban areas (more people, employment, etc. w/o commensurate growth in traffic -- bending but not breaking the curve).

- "Physics of transport" remains – parameters may change somewhat.

Toronto Central Area Office Occupancy Index
October 1, 2023

Index calculated as a percentage of pre-COVID occupancy.

The Index is supported by the City of Toronto, Downtown Yonge and Dowtown West BIA. It is a measure of the percentage of office employees returning to the office compared to the number of employees who would normally have come to their offices pre-COVID. For a detailed description of the calculation please contact Iain Dobson at idobson@srraresearch.org

Average weekly - 54%

Peak Day - Wednesday 69%

Slow Day - Monday 28%

Source: SRRA (2023)
https://srraresearch.org/covid/category/Occupancy%20Index

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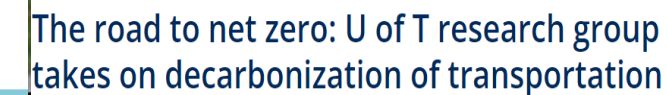
A Third Revolution? Shifting Attractors? (3)
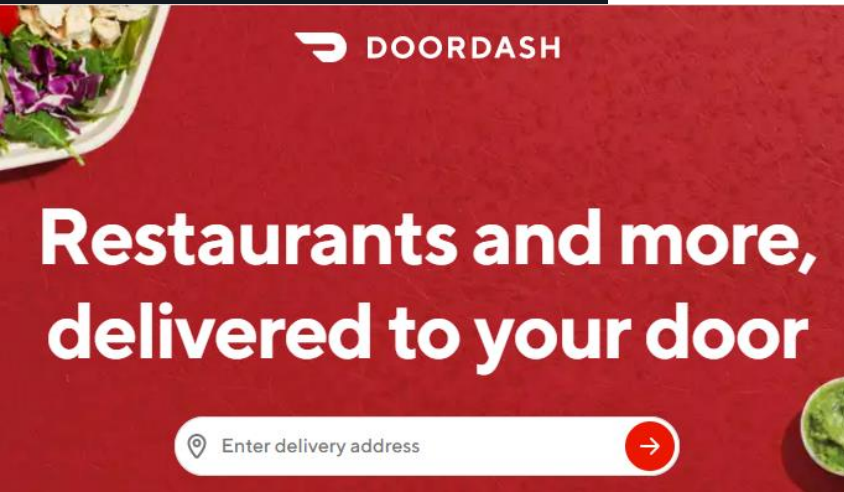
- Similarly, the pandemic has rapidly accelerated e-commerce, etc.
- Impacts on:
  - Travel, especially road-based trips.
    - Substituting delivery vehicles for person-based "shopping" trips.
  - Urban economy (retailing, entertainment, …).
- Again, would appear to be reinforcing the road-based attractor, not altering it.

A Third Revolution? Shifting Attractors? (4)

- EVs may decarbonize transport.
- But, this will not, in itself, shift the attractor to address many other important transportation issues:
  - Congestion.
  - Economic productivity / vitality / competitiveness.
  - Quality of life.
  - Equity.
  - Preservation of farm land & "natural areas".

Attachment B

TransformTO
Net Zero Strategy
A climate action pathway to 2030 and beyond

November 2021

UNIVERSITY OF TORONTO

University of Toronto researchers re-envisioning our energy systems

The Climate Positive Energy Initiative is the University of Toronto's centre for interdisciplinary clean energy research. Linking science, social science, engineering, economics and policy researchers to transform our energy systems.

U of T News

The road to net zero: U of T research group takes on decarbonization of transportation

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A Third Revolution? Shifting Attractors? (5)

- CAVs: Who knows?
- But most likely they will reinforce the auto-centric attractor.

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A Third Revolution? Shifting Attractors? (6)

- Massive, dynamic data are available in ever-increasing volumes concerning all aspects of urban life, including travel.

- AI-based data analytics & computing power are enabling us to "see" and (hopefully) understand the city as never before.

- Telecommunications are increasingly substituting for travel in ways not seen before.
  - Virtual, rather than physical, accessibility.

Tracking residential relocations during the pandemic with cellphone data
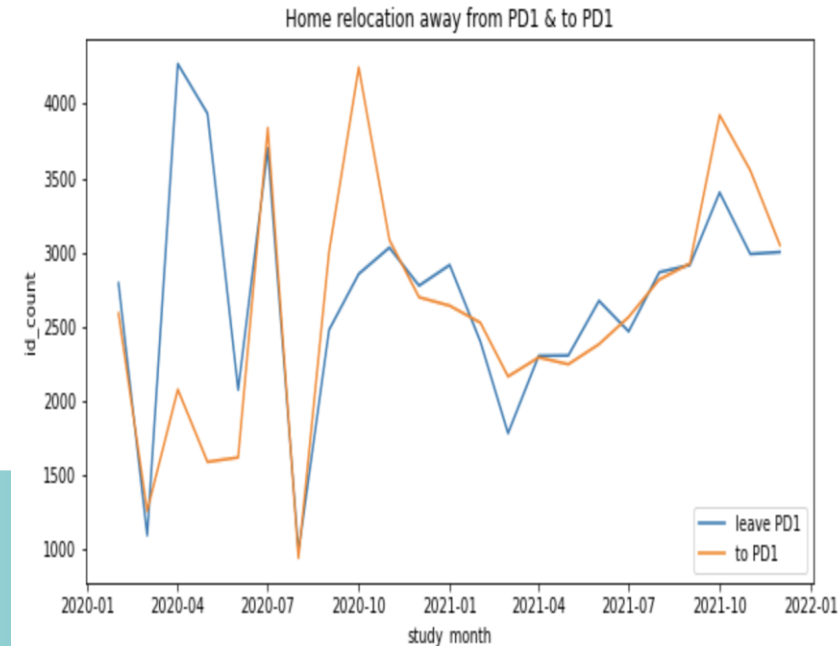
Microsoft Teams meeting

Join on your computer or mobile app
Click here to join the meeting

Or join by entering a meeting ID
Meeting ID: 224 251 214 578
Passcode: PXCF5P

Learn More | Meeting options

Home relocation away from PD1 & to PD1

A Third Revolution? Shifting Attractors? (7)

- Technology, in the form of new mobility services, etc. is not, in and of itself, going to generate a "third revolution" – i.e., a fundamental change in "the urban attractor".
- This is going to need a "revolutionary" new approach to urban design that:
  - Shifts the attractor away from auto-dominance to more "sustainable" modes of travel.
  - Is able to accommodate continuing urban growth (population, economic activity) with a much "lighter footprint" wrt:
    - Land.
    - Environmental impact.
    - Quality of life (social equity).
- I.e., the "third revolution" (if it is to happen) will be one of land use / urban form "driving" the land use – transport interaction, not the reverse (which has been the case throughout history to date).
  - Not an easy (or a quick) thing to achieve!

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A Third Revolution? Shifting Attractors? (8)

- What role can data & data analytics play in this re-invention of the transportation – land use interaction & urban design?
  - Balancing virtual and physical accessibility & interactions.
  - Re-inventing public transportation.
  - Restoring housing affordability.
- How can a system of systems approach help us to find the "leverage points" to shift the city attractor to greater sustainability?
  - Role of generative design?

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And, a final word …

- "Complete communities" / "15-minute cities" are one starting point for this discussion. But:
  - These are new labels for ideas that have been around for decades (at least).
- Need a <u>systems approach</u>.
- Need to recognize:
  - The "realities on the ground".
    - Political.
    - Economic.
    - A <u>huge</u> investment in existing buildings, infrastructure, etc.
  - Scalability at the regional level.
  - Practical pathways from "here" to "there".
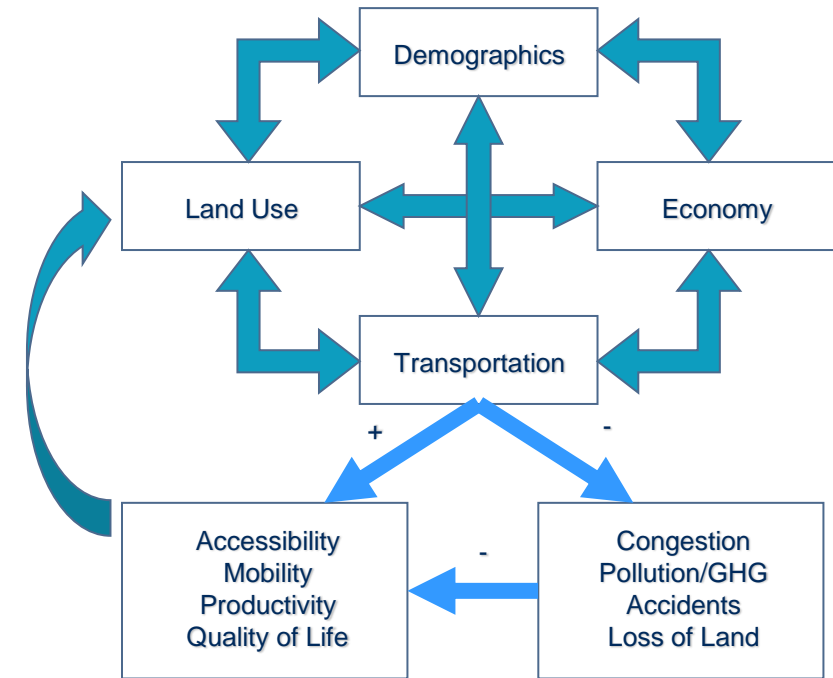
Thank you.

Let's discuss!

"We know a tremendous amount about how the world works, but not nearly enough. *Our knowledge is amazing; our ignorance even more so.*"

Donella H. Meadows, Thinking in Systems: A Primer, edited by Diana Wright.

"*Find the beginning, the slight silver key to unlock it, to dig it out. Here then is a maze to begin, to be in.*"

Michael Ondaatje, "The Collected Works of Billy the Kid: Left-Handed Poems"