Explaining the rise in pedestrian fatalities, a systems approach (Phase 1)

Examining pedestrian safety impacts of congestion pricing policies using a system dynamics approach (Phase 2)

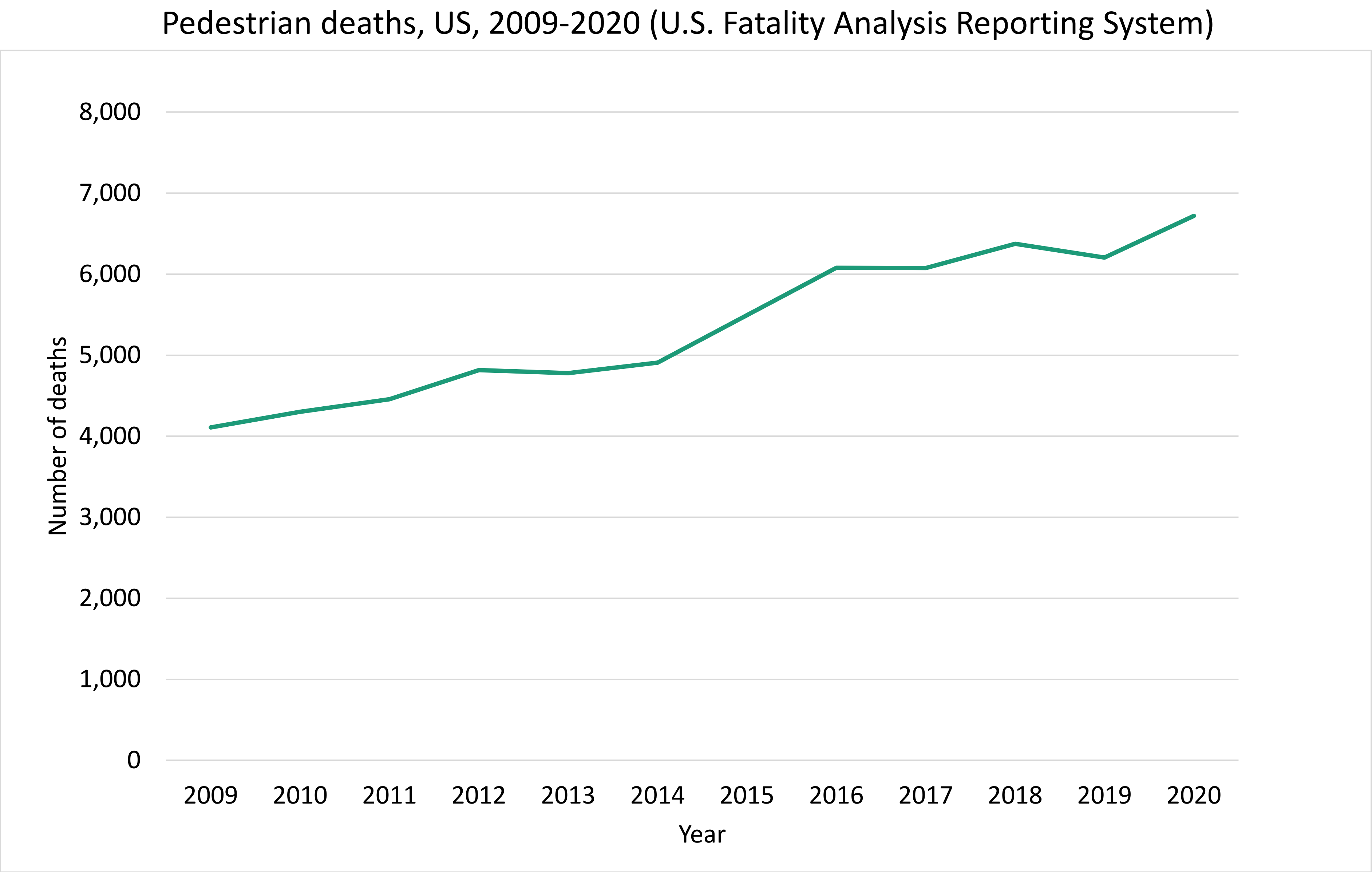
Becky Naumann, Jill Kuhlberg, Kristen Hassmiller Lich,

Nasim Sabounchi, Bhavna Singichetti, Steve Marshall, Laura Sandt

Evolution of this Work

- Examining the interconnectedness and complexity potentially generating pedestrian death trends (RR1)
- Honing in on the ripple effects of a specific policy on this trend in a specific geographic area (R21)
  - Understanding the research and current state of the evidence base on this policy (i.e., congestion pricing policies).
  - Model potential policy impacts on pedestrian injuries

Using SD to examine the increase in pedestrian deaths



Walking while drunk fuels surge in US pedestrian deaths

Updated Aug 6; Posted Aug 6

Distracted walking could be a contributor to the nearly 6,000 pedestrian deaths in 2017

UT Police are warning students that texting and walking can be dangerous.

Author: Brandon Bates

Published: 9:51 PM EDT August 27, 2018

Updated: 8:18 AM EDT August 28, 2018

The rise in SUVs is linked to a surge in pedestrian deaths

By Jill Petzinger • May 8, 2018

Where Pedestrian Deaths Are Up, Is Marijuana to Blame?

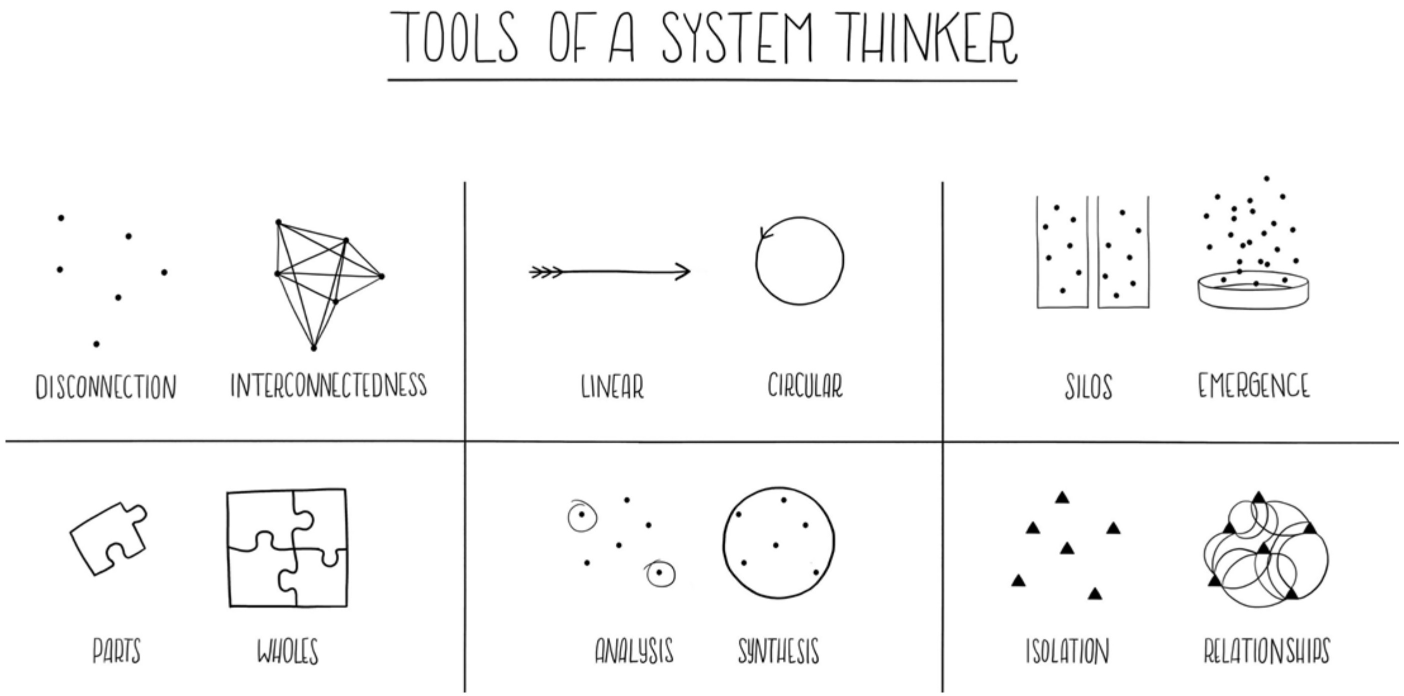
Marijuana buds being stripped from stalks in Denver. Data from Colorado and other states that have legalized recreational marijuana "is a marker for concern," the author of a study by the Governors Highway Safety Association said. Ryan David Brown for The New York Times

By Neal E. Boudette

Feb. 28, 2018

What is systems thinking and what are systems approaches/tools?

- Practical, structured inquiry, which…
- Seeks to "see" wholes, and
- Supports development and/or testing of a model (qualitative or quantitative) representing critical components of the system that determine an outcome(s)



https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a

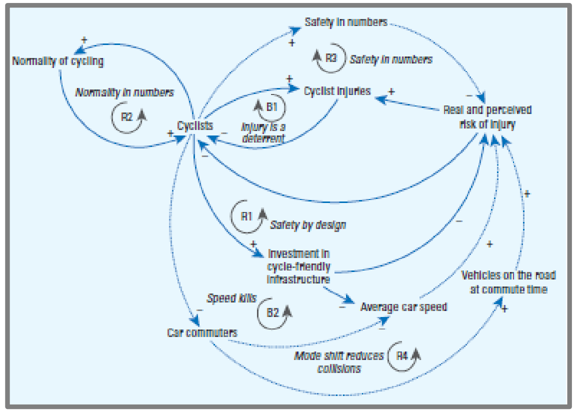
Some Systems Science Tools

Qualitative

- AcciMap
- 5 Rs
- Balance of petals mapping
- Goal and action alignment mapping
- Causal loop diagramming
- Network mapping
- System support mapping

Quantitative

- System dynamics simulation (stock and flow simulation)
- Agent-based models & microsimulation
- Network analyses
- Discrete event simulation



Source: Macmillan, 2014

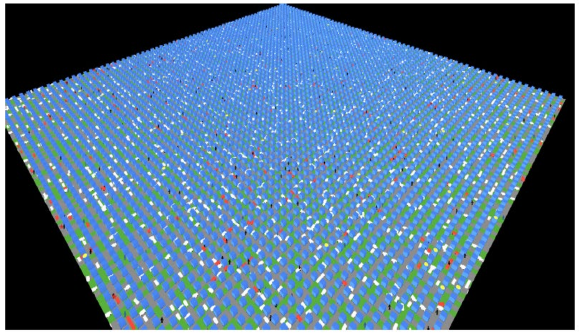


Fig. 3. Three dimensional view of the simulated transport system showing buildings (blue), cars (white), cars that have recently recorded seeing a cyclis (red), cyclists (black), roads (grey), and road segments with separated cycling infrastructure (green). (For interpretation of the references to colour in thi figure legend, the reader is referred to the web version of this article.)

Macmillan A, Woodcock J. Understanding bicycling in cities using system dynamics modelling. *J Transp Health*. 2017;7(Pt B):269-279. doi:10.1016/j.jth.2017.08.002

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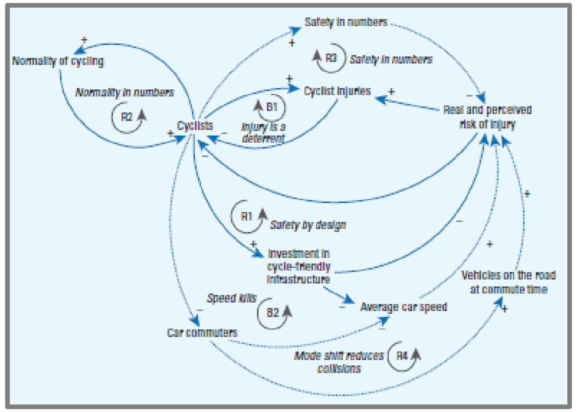

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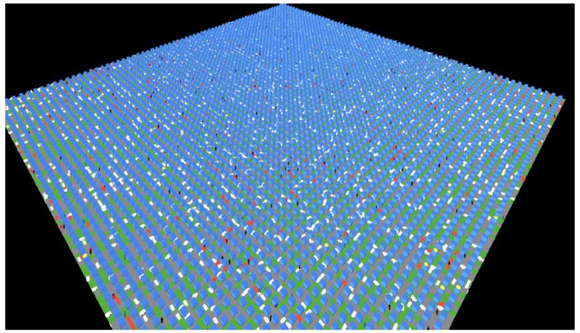

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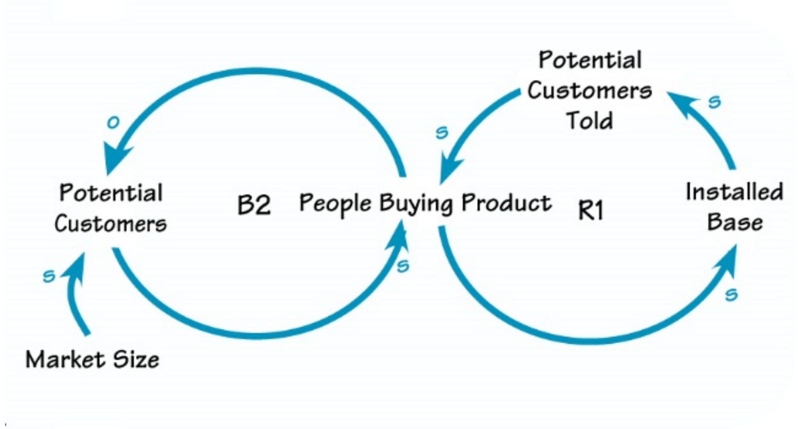
Causal Loop Diagramming and System Dynamics (SD) Modeling

"System dynamics is the use of informal maps and formal models with computer simulation to uncover and understand endogenous sources of system behavior."



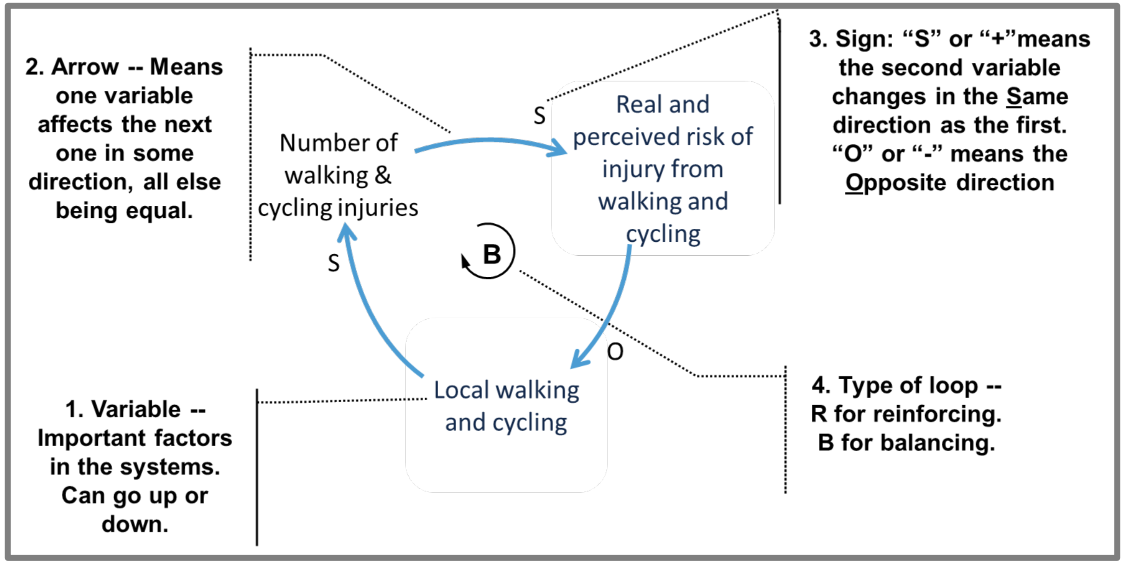
Richardson, G.P. (2011). Reflections on the foundations of system dynamics. *System Dynamics Review, 27*(*3*), 219-243.
https://thesystemsthinker.com/step-by-step-stocks-and-flows-converting-from-causal-loop-diagrams/

Using SD to examine the increase in pedestrian death rates

- Illuminate core assumptions and uncertainties related to increase in pedestrian deaths
- Enrich our hypotheses. Develop specific, dynamic, and testable hypotheses
- Understand future data collection and research needs

Systems Workshops: Group Model Building

- Group model building workshops, working with a diverse group of experts
- Developed system maps (causal loop diagrams)
- 3 workshops conducted. Attendees represented:
    - Law/ injury claims
    - Transit (local and state)
    - Local and state planners and pedestrian/bicycle coordinators
    - State DOT safety engineers
    - State Department of Health and Human Services
    - Law enforcement
    - Fire department
    - Journalism
    - Medicine/Trauma
    - Researchers (epidemiology, planning, robotics, engineering, child development, economics)
    - Automakers
    - Local elected officials (town council member)
    - Advocacy (injury prevention, AARP, coalition to end homelessness)

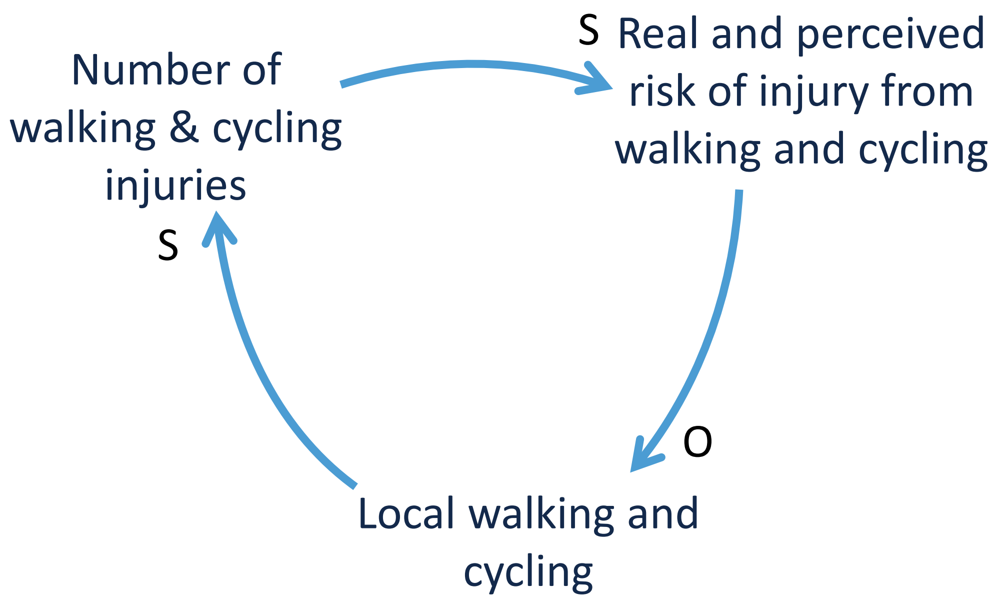


From linear thinking to thinking about feedbacks

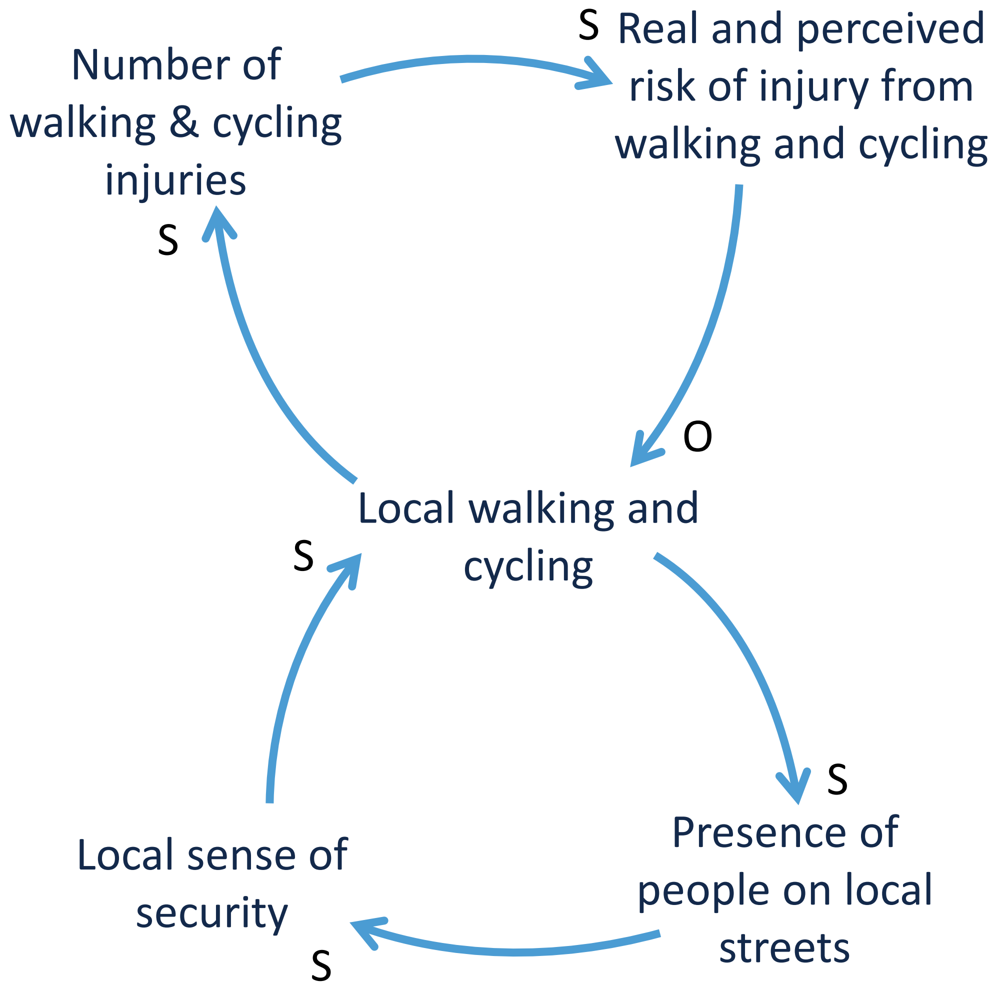
Real and perceived risk of injury from walking and cycling

Local walking and cycling

From linear thinking to thinking about feedbacks



From linear thinking to thinking about feedbacks



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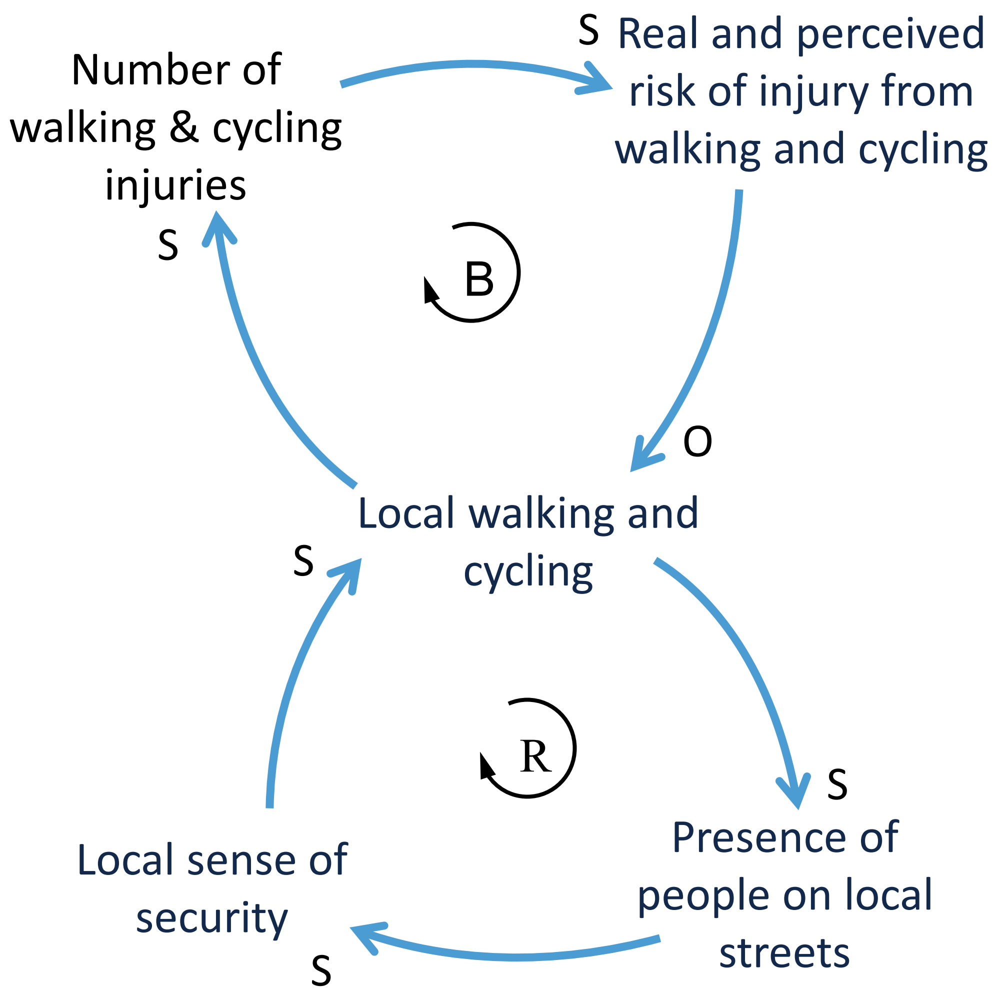
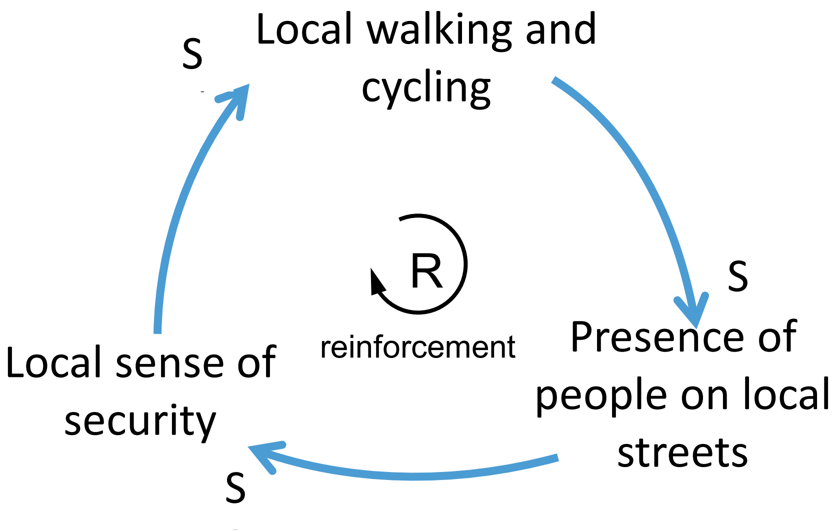
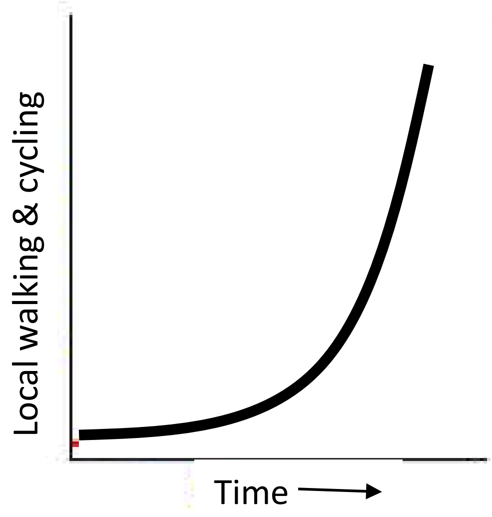


UNC INJURY PREVENTION RESEARCH CENTER

A feedback loop that builds on itself is called a “reinforcing loop”: engines of growth

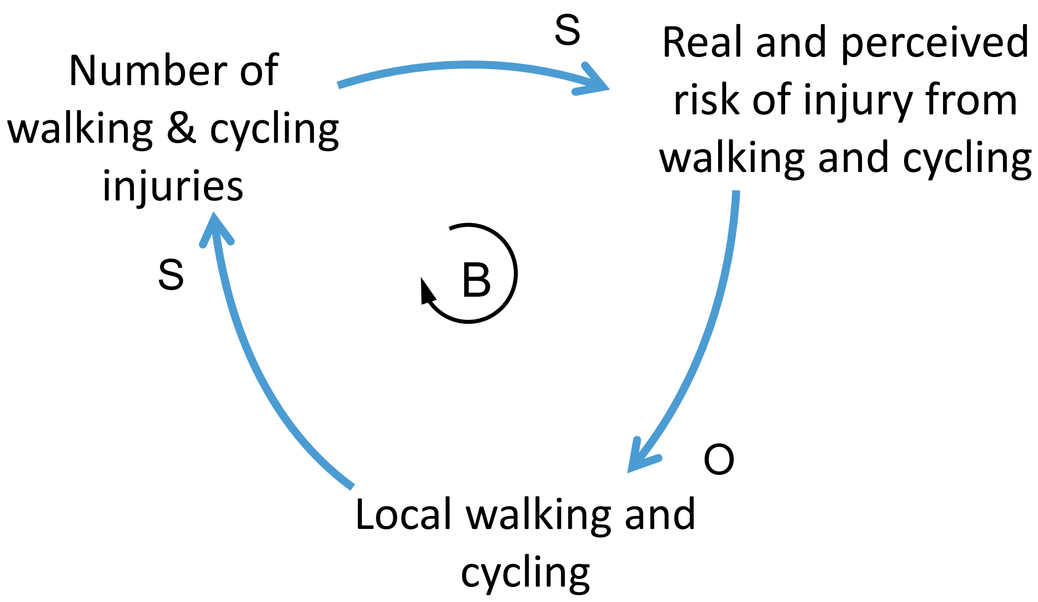
- They are also called positive feedback loops, virtuous cycles, vicious cycles, bandwagon effects, snowball effects
  - Changing a variable in one direction produces a response in the same direction of that variable
  - Drivers of exponential growth

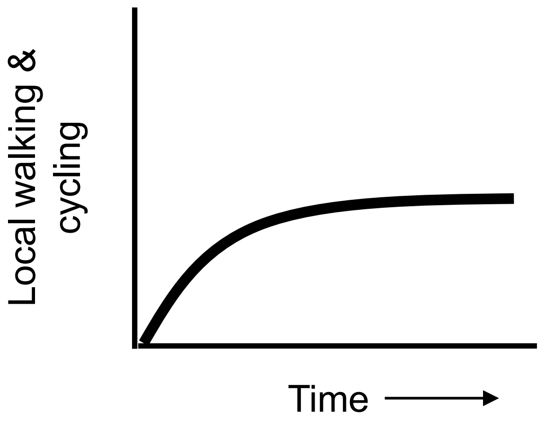




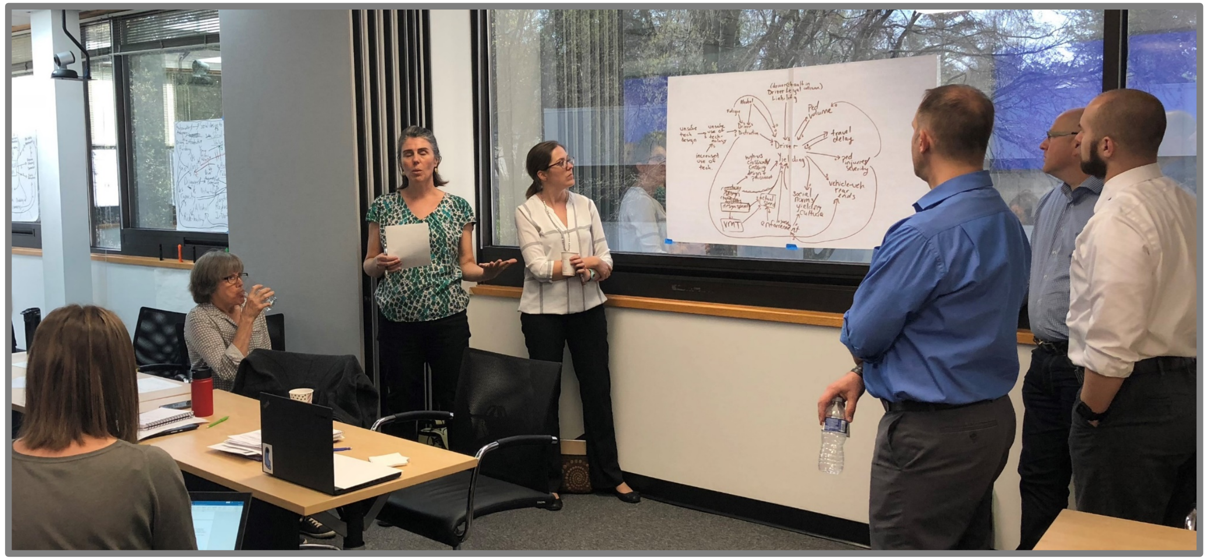
Balancing loops seek balance or equilibrium: counteract change

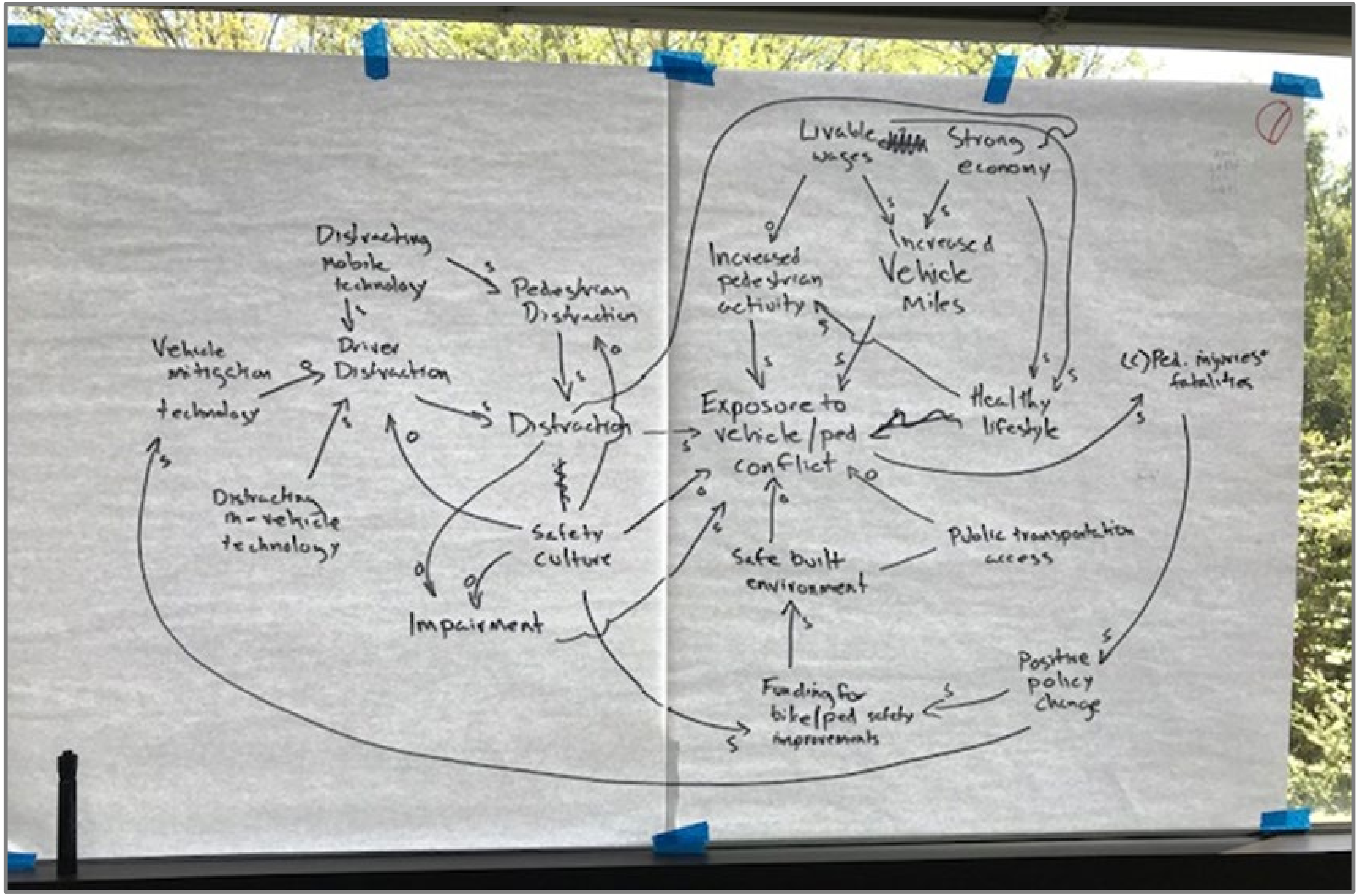
- Balancing loops are created when there are an odd number of negative links (or O's).
- "Goal seeking"

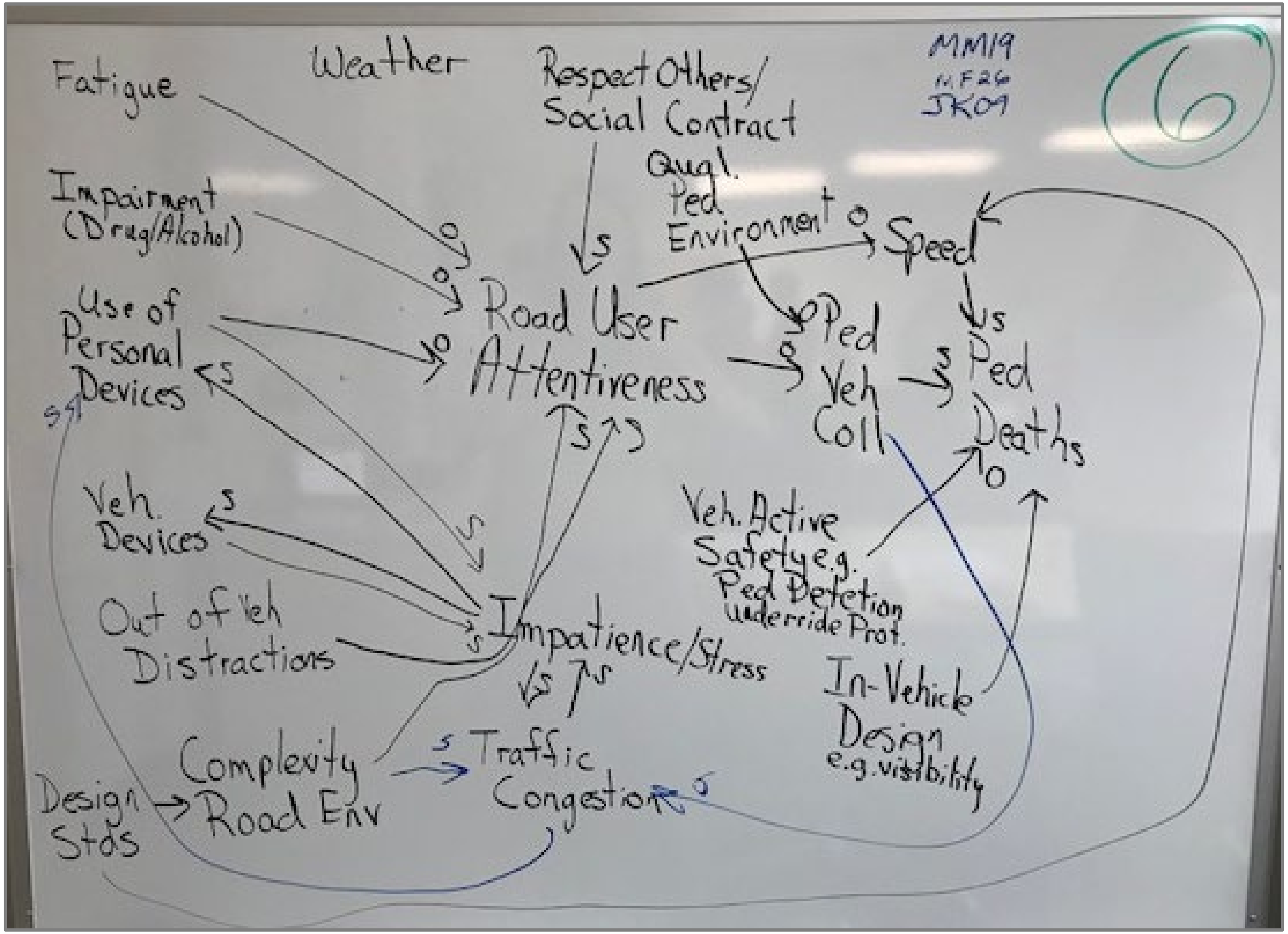




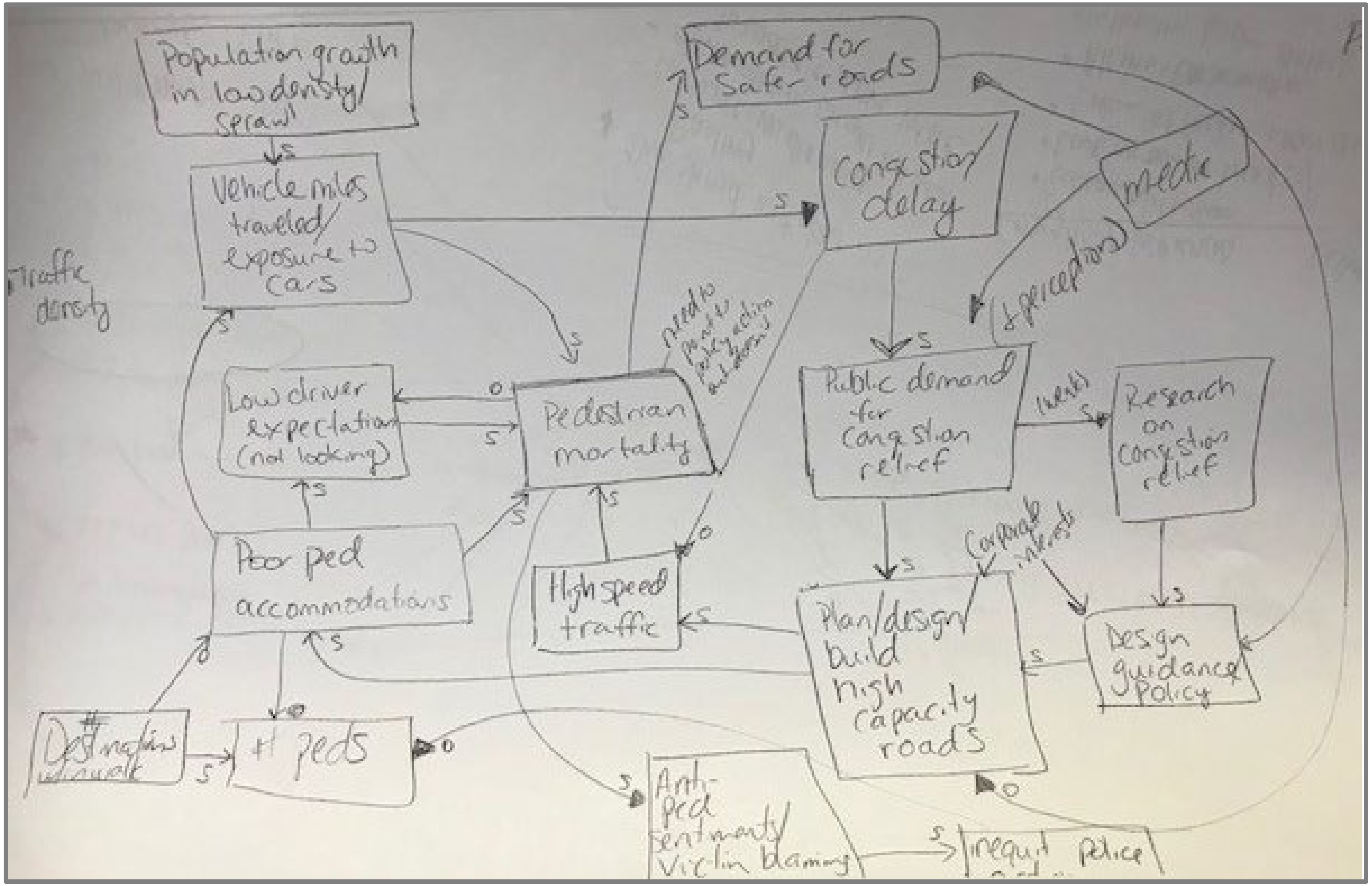



Livable wages
Strong economy
Increased pedestrian activity
Increased Vehicle Miles
Distracting mobile technology
Pedestrian Distraction
Vehicle mitigation technology
Driver Distraction
Distraction
Exposure to vehicle/ped conflict
Healthy lifestyle
(c) Ped. injuries + fatalities
Distracting in-vehicle technology
Safety culture
Public transportation access
Safe built environment
Impairment
Positive policy change
Funding for bike/ped safety improvements



MM19
JF26
JK09
6
Fatigue
Weather
Respect Others/
Social Contract
Qual.
Ped
Environment
Speed
Impairment
(Drug/Alcohol)
Use of
Personal
Devices
Road User
Attentiveness
Ped
Veh
Coll
Ped
Deaths
Veh.
Devices
Veh. Active
Safety e.g.
Ped Detection
underride Prot.
Out of Veh
Distractions
Impatience/Stress
In-Vehicle
Design
e.g. visibility
Complexity
Road Env
Traffic
Congestion
Design
Stds

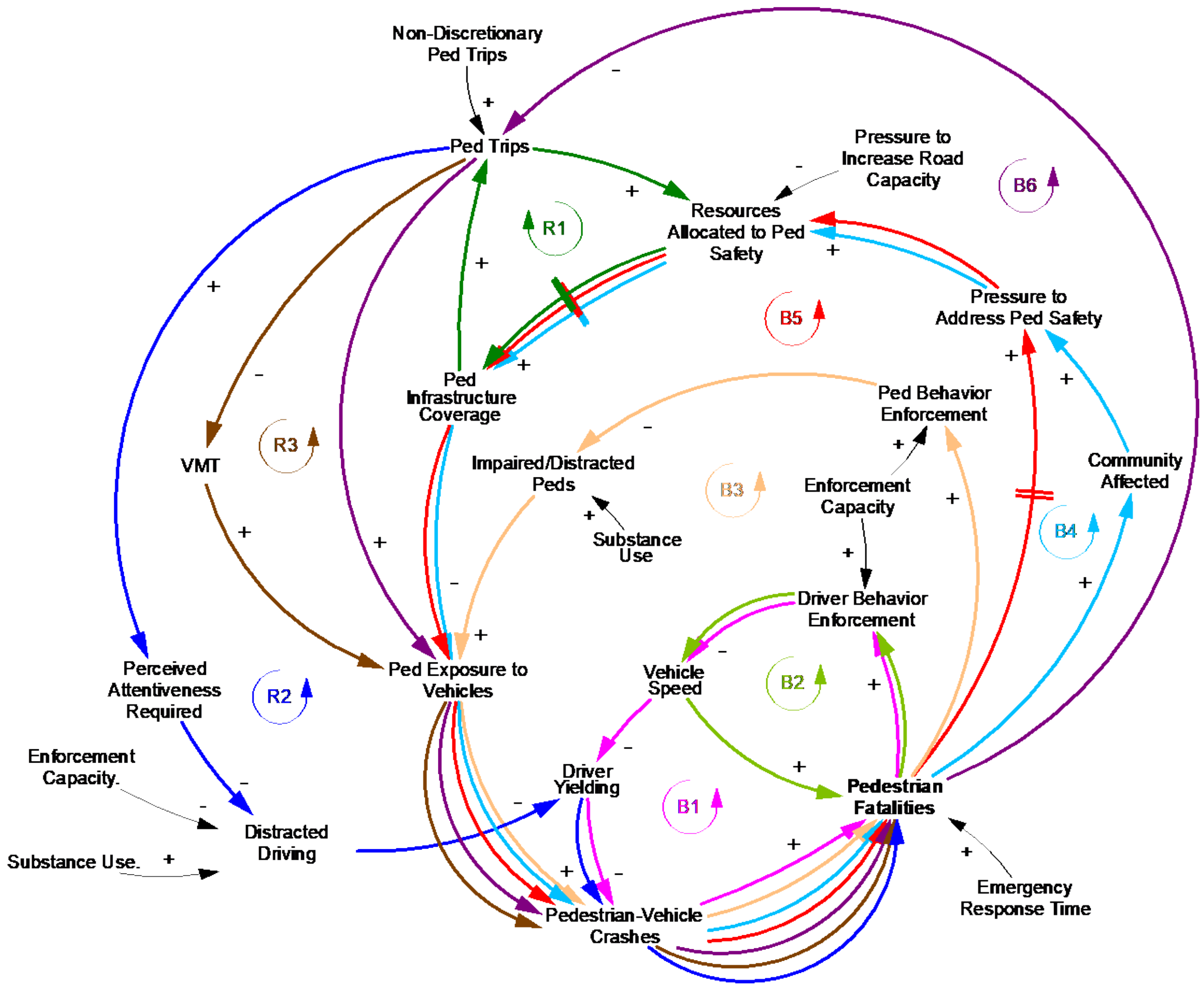

Population growth in low density/ sprawl
Vehicle miles traveled/ exposure to cars
Traffic density
Demand for Safer roads
Congestion/ delay
media
perception
Low driver expectation (not looking)
Pedestrian mortality
need to point to policy action
Public demand for congestion relief
Research on congestion relief
Poor ped accommodations
High speed traffic
Corporate interests
Plan/design build high capacity roads
Design guidance Policy
Destination walk
peds
Anti-ped sentiment/ Victim blaming
inequit police

Post-Workshop Insights

- Perspectives on the nature of the issue and potential solutions changed after the workshop
- Acknowledged & recognized the limitations of existing data in telling the full story and in identifying solutions
- Appreciated the complexity of the issues more and the chance to think more deeply about the issues; the mapping approach was a thought-provoking way to generate and inspire research ideas
- Some participants (from non-transportation fields) reported better seeing how their work relates to pedestrian safety
- New collaboration opportunities emerged

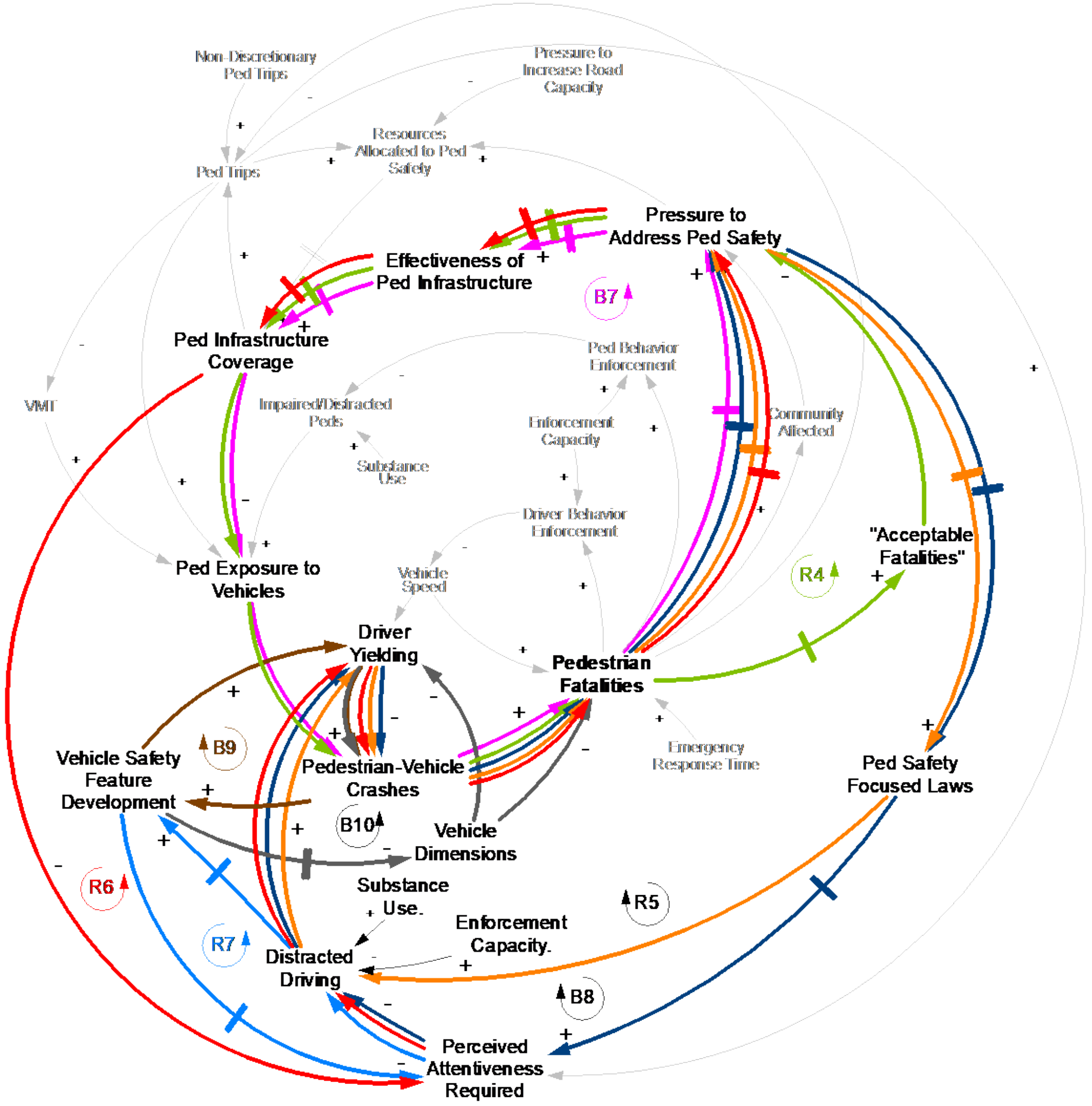
Source: www.pedbikeinfo.org/Dan Gelinne

Synthesizing the Data: Community-level System Structure



Source: Naumann RB, Kuhlberg J, Sandt L, et al. Integrating complex systems science into road safety research and practice, Part 2: applying systems tools to the problem of increasing pedestrian death rates. Inj Prev. 2020;26(5):424-431.

Synthesizing the Data: Factors Outside of a Community



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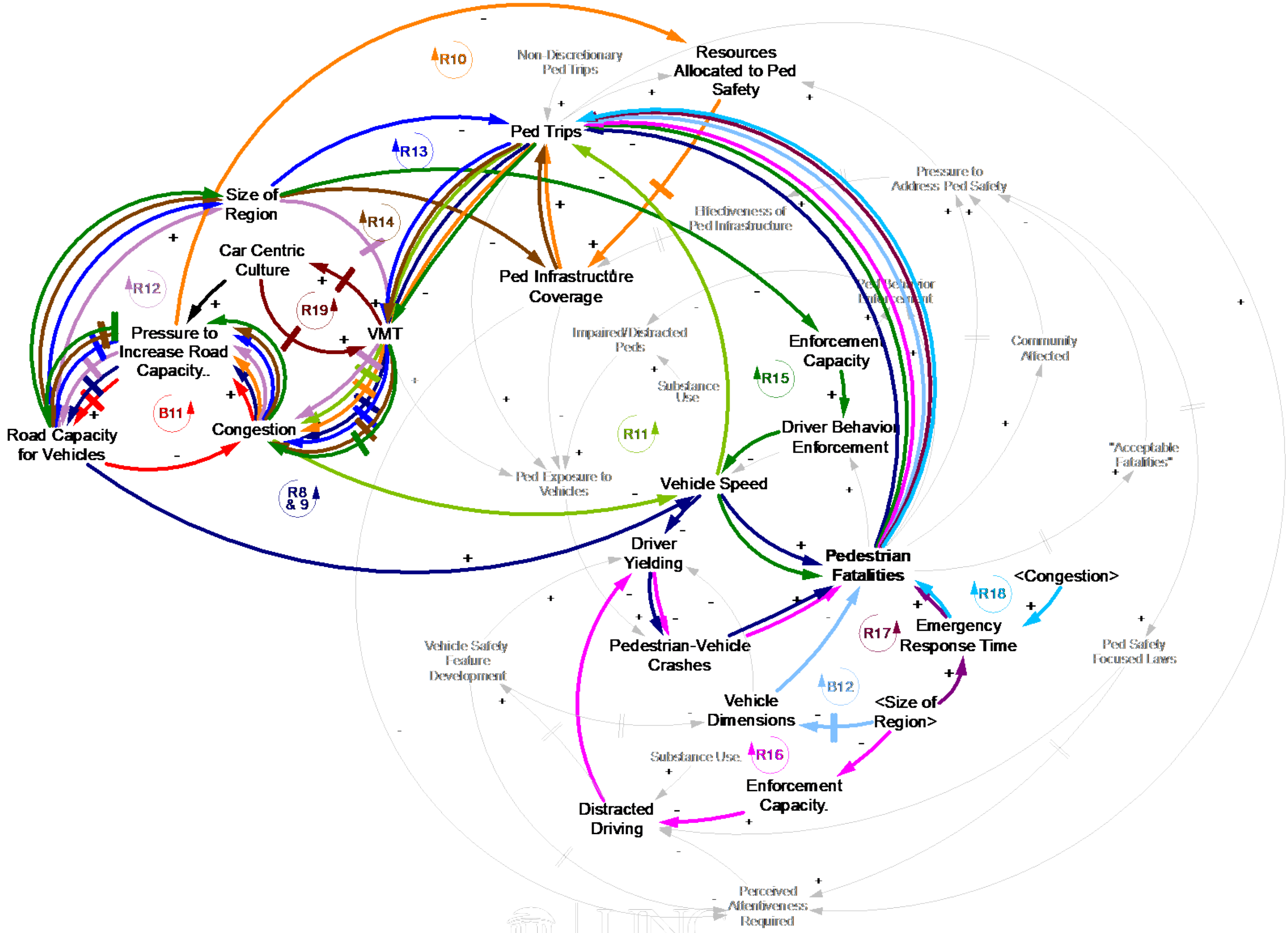
Synthesizing the Data: Factors Related to Regional Growth and Vehicle Miles Traveled



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More information….

- Naumann RB, Kuhlberg J, Sandt L, Heiny S, Apostolopoulos Y, Marshall SW, Hassmiller Lich K. **Integrating complex systems science into road safety research and practice, Part 1: Review of formative concepts**. Injury Prevention. 2020;26(2):177-183.

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- Examining the interconnectedness and complexity potentially generating pedestrian death trends (RR1)
- **Honing in on the ripple effects of a specific policy on this trend in a specific geographic area (R21)**
  - Understanding the research and current state of the evidence base on this policy (i.e., congestion pricing policies).
  - Model potential policy impacts on pedestrian injuries

Honing in on the system and dynamic complexity affecting pedestrian safety in NYC

- Congestion pricing policies (CPPs) are a travel demand management strategy designed to reduce peak-period traffic volumes by financially encouraging road users to use alternate transport modes, eliminate trips, or travel at different times.
- Several U.S. cities are considering CPPs, and New York City (NYC) plans to implement a CPP in 2022.

https://www.theverge.com/2019/3/29/18286830/congestion-pricing-nyc-gridlock-autonomous-vehicles-traffic

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Bibliometric analysis of congestion pricing policy research

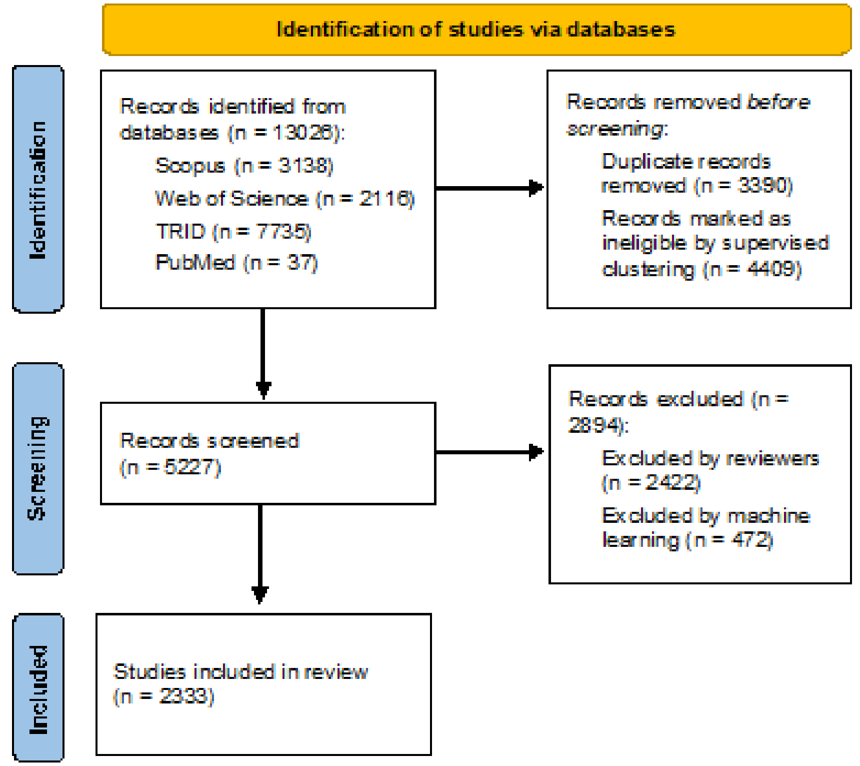


Fig. 1. PRISMA Flow Diagram for Congestion Pricing Bibliometric Analysis*
*Modified for a bibliometric analysis with no screening of full-text studies.

- Prioritized references for manual screening using a two-phase, automated approach that relied on semi-supervised learning and machine learning.
- Networks were constructed using the VOSviewer application, based on available data fields in the four databases.
- Network maps describing:
    1. distribution of and relationships between key terms
    2. frequency of publications and collaborations between authors
    3. authors’ countries from which the research originated.

Clusters of terms commonly identified in titles and abstracts of congestion pricing publications

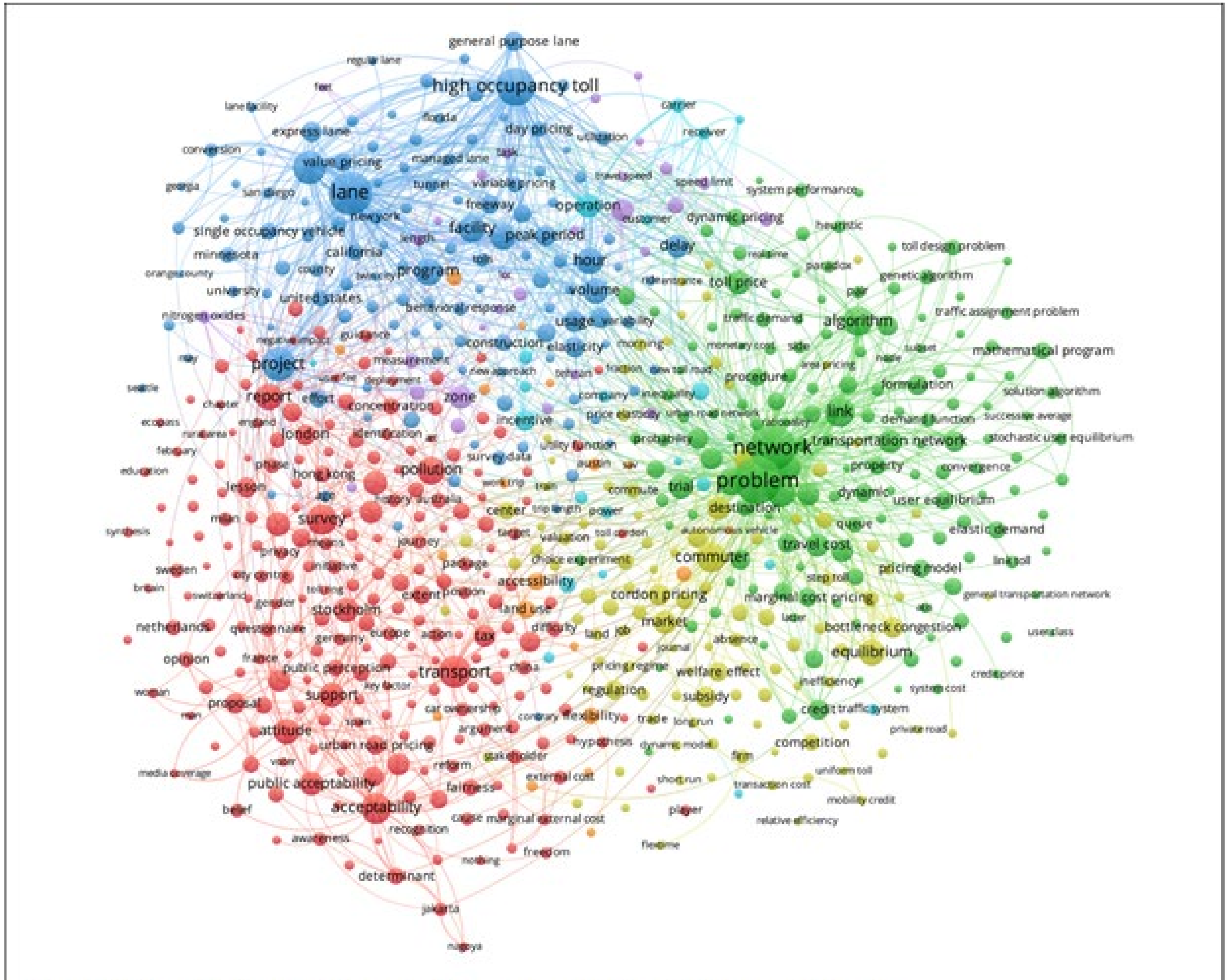
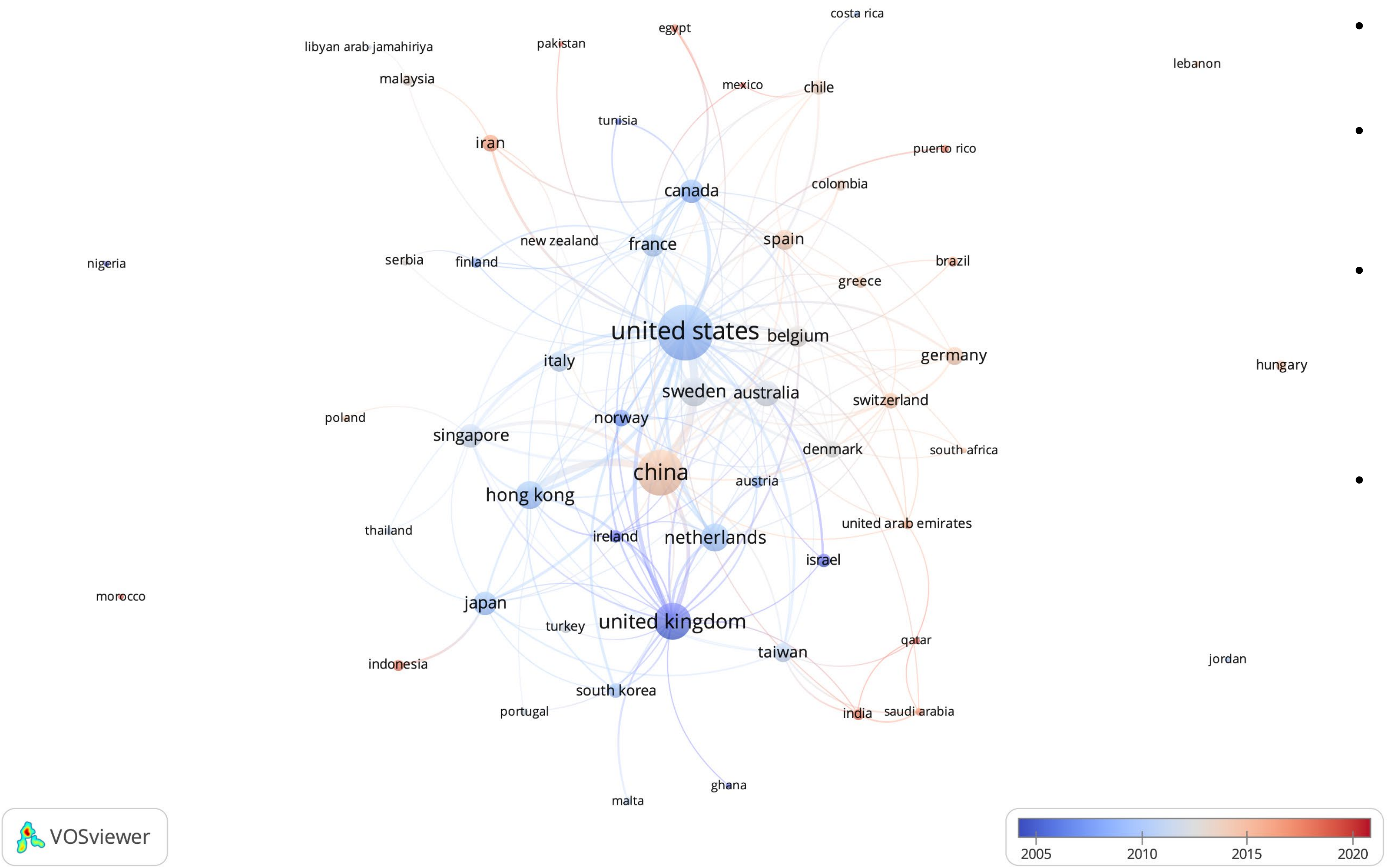


Fig. 2. Title and Abstract Terms in Congestion Pricing Bibliometric Review

- Seven clusters were identified
- 3 largest clusters are distinguished by blue, green, and red.
- Blue focuses on a range of structural implementation terms and policy types, including terms such as ‘high occupancy toll’, ‘facility’, ‘lane’ and ‘peak period’.
- Green cluster includes terms that focus on transportation modeling methods and characteristics, including ‘network’, ‘algorithm’, ‘dynamic,’ ‘link,’ ‘formulation.’
- Red includes terms related to population perceptions of congestion pricing policies, such as ‘attitude’, ‘acceptability’, and ‘support’, and effects relevant to perception such as ‘pollution’ and ‘external costs.’
- A general shift in terminology from terms related to implementation in the early 2000s toward terms related to acceptability after 2010.

Patterns in Country Representation



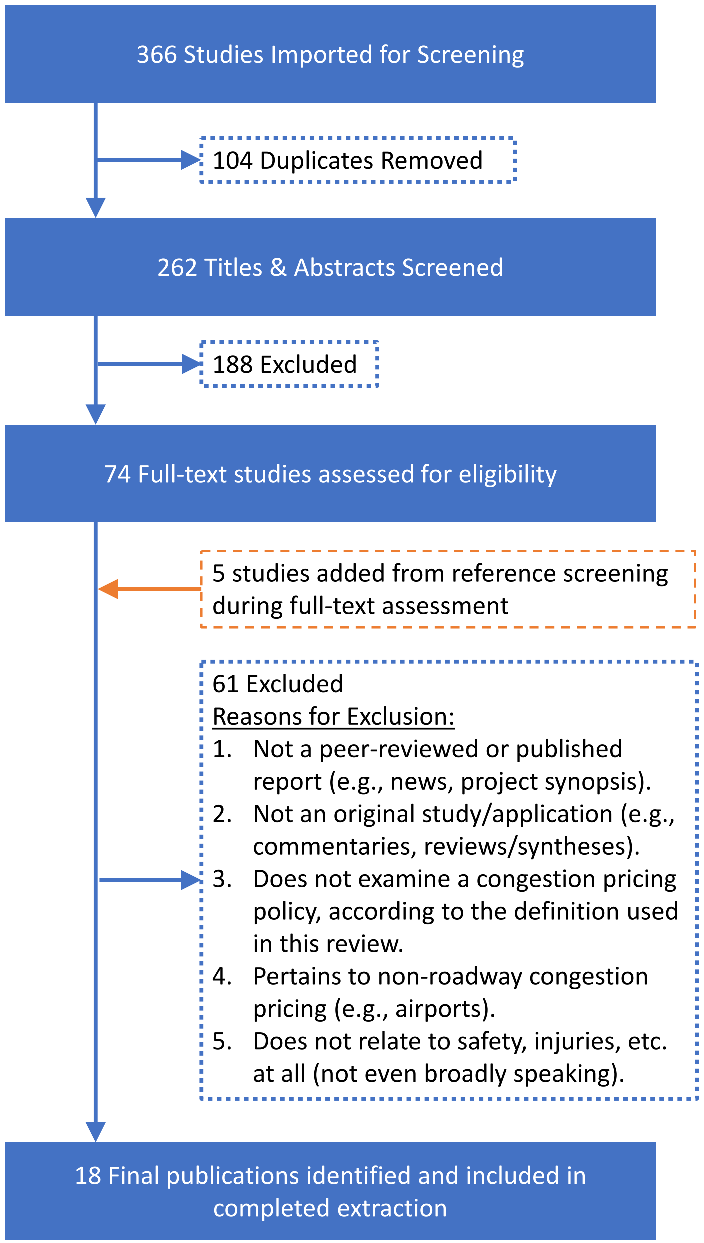
- Top countries represented in the literature were the US (n=439), China (n=265), the United Kingdom (n=154), Sweden (n=86)
- UK had an average publication year of 2005. By 2009, publication patterns shifted to include the US, the Netherlands (n=77), Canada (n=51), and Hong Kong.
- Sweden and Australia (n=59) gained greater representation, on average, in late 2011 and early 2012, after which patterns shifted to include China, Iran (n=22), Spain (n=33), Germany (n=23), and Switzerland (n=17).
- Most recently, research representing countries such as Indonesia (n=9), India (n=7), Puerto Rico (n=3) and Qatar (n=2) have also started to appear in published research

Key takeaways

- Number of publications grew significantly between 1956 and 2015, with annual research output increasing from just 1 in 1956 to 122 in 2015.
- Wide variety of topic areas were studied: congestion pricing implementation logistics, public perception and acceptability, and network algorithms.
- Country representation revealed notable shifts in research output across the globe as countries explored policy implementation with early research productivity in the UK, moving to the US (and other countries such as the Netherlands, Canada, and Japan), and eventually countries such as China, Germany, and Iran.
- Several topic gaps were identified in this analysis. Terms related to equity and impact were only in a small proportion of titles and abstracts. Also, terms relevant to specific road user types and modes (e.g., pedestrian, motorcycle[ist], bicycle[ist]) and terms related to safety were extremely sparse in titles and abstracts.

- More information: Singichetti B, Dodd A, Conklin JL, Hassmiller Lich K, Sabounchi NS, Naumann RB. **Trends and insights from congestion pricing policy research: a bibliometric analysis.** 2021. Under Review at *Transportation*.

Safety-related congestion pricing studies



Article	Congestion Pricing Policy(ies) Examined	Study setting and time period	Is Safety primary focus?	Safety outcomes measured	Key Conclusions
Yu et al. The cost-effectiveness of competing congestion pricing plans in New York City. (2019)	1. Zone-based policy, with trucks subject to per-axle toll and exemption for taxis/for-hire vehicles. Tolls do not vary by time, but vary based on area (e.g. higher in areas with other public transit options), and charges collected on the perimeter of the zone (including bridge tolls) 2. Zone-based policy introduced in phases, with time-varying charges (e.g. time of day and weekday vs weekend), with traffic monitoring within the zone	New York City, USA. Hypothetical 10-year data for simulated policies.	Yes (as part of health benefits)	The health outcome measured was the quality-adjusted life year (QALY), indicating the quality and the quantity of life lived	Both proposals were found to be cost-saving/cost-effective, and have the same long-term costs and health benefits, including life expectancy gains and health benefits.
Wier et al. Health Effects of Road Pricing in San Francisco, California. (2011) *	Zone-based policy with time-varying tolls (time of day)	San Francisco, California, USA. 2005 real non-policy data compared to simulated 2015 policy and non-policy data	Yes	Vehicle-pedestrian injury; vehicle-cyclist injury	Road pricing was projected to moderate the predicted increase in vehicle-cyclist injuries, and decrease vehicle-pedestrian injury collisions.
Percoco. The impact of road pricing on accidents: a note on Milan. (2016)	Zone-based policy, with time-varying (time of day and weekday vs weekend) charges collected when entering zone, exemptions for certain vehicles (e.g. motorbikes, alternative fuel vehicles), and exemptions or	Milan, Italy. 2001 - 2011 data involving a real policy established January 2008 (pre-vs post-policy comparison)	Yes	Accidents, deaths, and injuries	A significant reduction in accidents and injuries was observed. A slight, non-significant, reduction was observed in deaths.

Overall study characteristics and key findings

- Published between 1989 to 2021
- United Kingdom (n=9), other European countries (n=5), US (n=4)
- Mostly examined zone- and cordon-based (n=13) schemes
- Most studied crashes broadly
- Crashes: Estimated reductions of the number of road traffic crashes following policy implementation included 3.6% per year in Stockholm's' zone-based charging area and 35% per month in London's zone-based charging area
- Fatalities: Varied. No observed changes in the three years following policy implementation in Milan to decreases as high as 33% in the two years following implementation in London.
- Injury Crashes: Estimated that through three years post-implementation, traffic changes caused by the London zone-based charging scheme were ultimately responsible for the reduction of 40-70 additional injury crashes per year beyond the crash reductions that were expected to occur as the result of all road safety initiatives and a general declining trend in road traffic crashes. Spain: an area-wide CPP documented increases in observed injury crashes, as a result of traffic patterns shifting to non-tolled areas

Mode-specific findings

- Motorcyclists: a 5.7% increase in total motorcycle casualties (in the year immediately post-CPP implementation, with a 17.3% increase in the number killed or seriously injured). Other estimates: no significant changes in motorcyclist casualties within the London charging zone during the same post-implementation period; however, increase immediately adjacent to the charging zone.

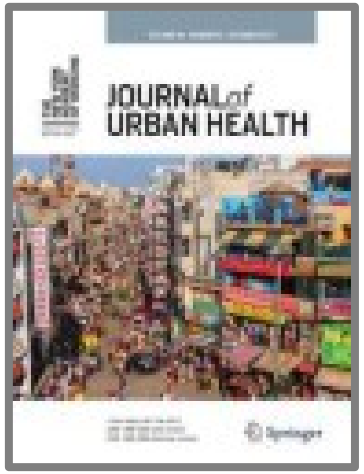
- Bicyclists: Observed and estimated changes in bicycle crashes and injuries varied in magnitude and direction, particularly based on time since CPP implementation. 13.3% increase in bicycle injuries resulting from crashes during the year immediately following London CPP implementation with a decrease several years after implementation in London. Attributed observed increases in the number of bicyclist injuries due to mode shifts and increases in bicycle use.

- Pedestrians: No significant change in the proportion of crashes affecting pedestrians in London (compared to vehicle occupants/riders) in the year immediately following implementation, but then observed increases in this proportion in years two and three post-implementation.

Key Takeaways

- Potential safety benefits for some road users following CPP implementation.
- Benefits may vary by road user type and according to length of time post-implementation.
- Relative paucity of research specifically exploring the safety outcomes of these policies, along with the wide breadth of CPP types, implementation contexts, outcomes measured, and relationships modeled indicate a need for additional research.
- Before implementing CPPs, cities/regions should consider, within the context of their own community, potential mode shifts and safety-related supports for such mode shifts, appropriate revenue reinvestment, and benefits in both short- and long-term time frames.

- More information: Singichetti B, Conklin JL, Hassmiller Lich K, Sabounchi N, Naumann RB. **Congestion pricing policies and safety implications: a scoping review.** *Journal of Urban Health*. 2021. In press.



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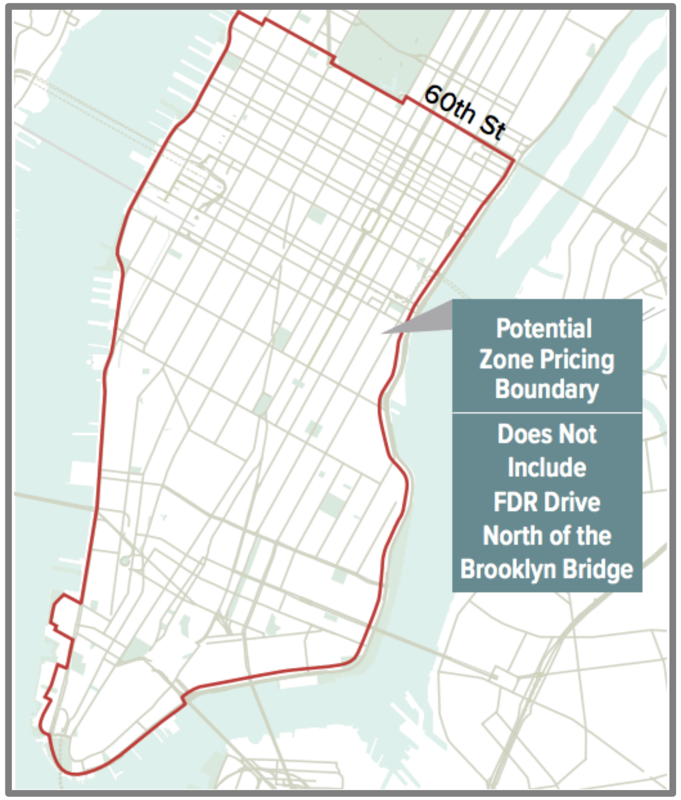
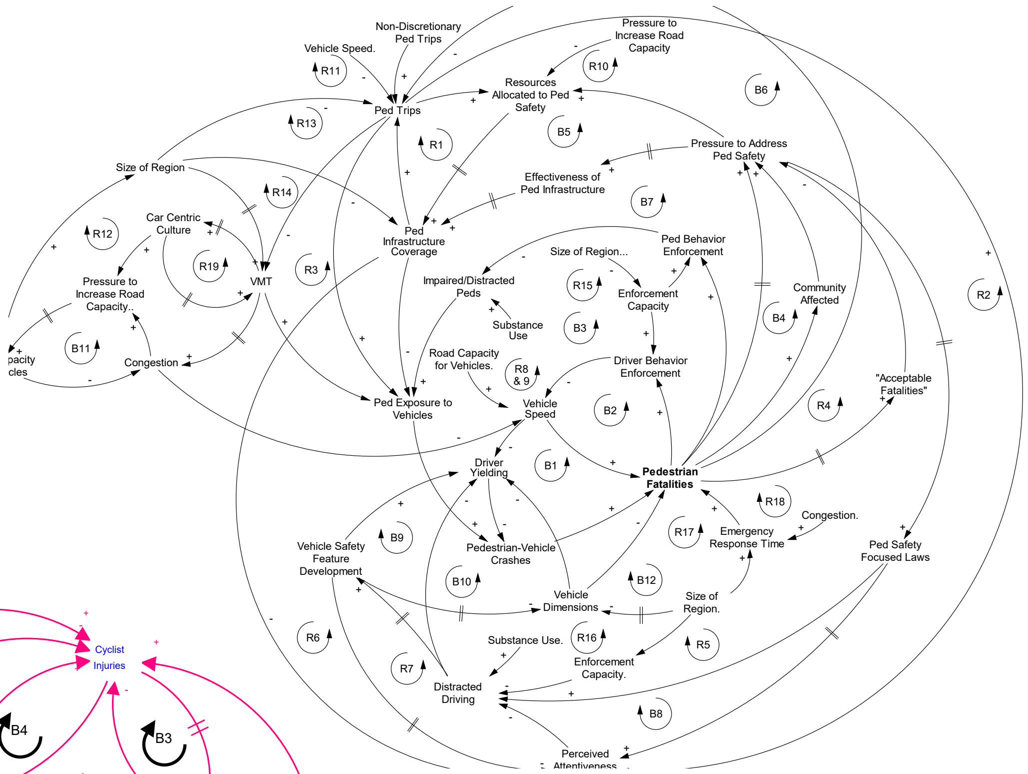
Honing in on the system and dynamic complexity affecting pedestrian safety in NYC

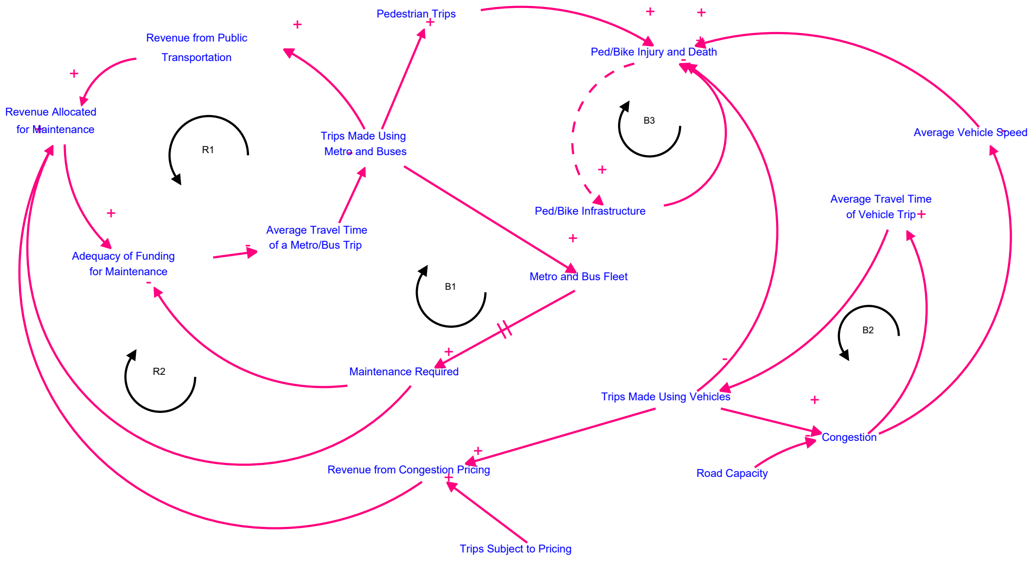
- NYC planning to implement CPP in 2022. Facing several unique challenges with respect to mode availability and increasing injury trends, despite infrastructure investments
  - Prior to the COVID-19 pandemic, the bus and metro systems were running at peak capacity in many places and had recently experienced reduced ridership due to slower and unreliable travel times
  - Additionally, beginning in 2014, the city had made significant investments in pedestrian and cyclist infrastructure over the last few years through their Vision Zero initiative.
- Can (and if so, how can) the NYC congestion pricing policy improve safety for road users (and namely, pedestrians), while meeting the intended purpose of reducing congestion and improving alternate travel modes?

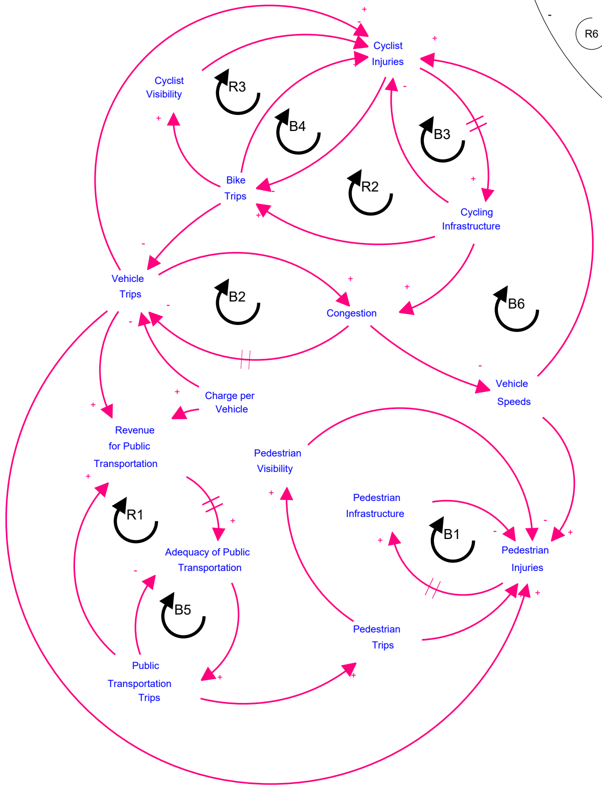


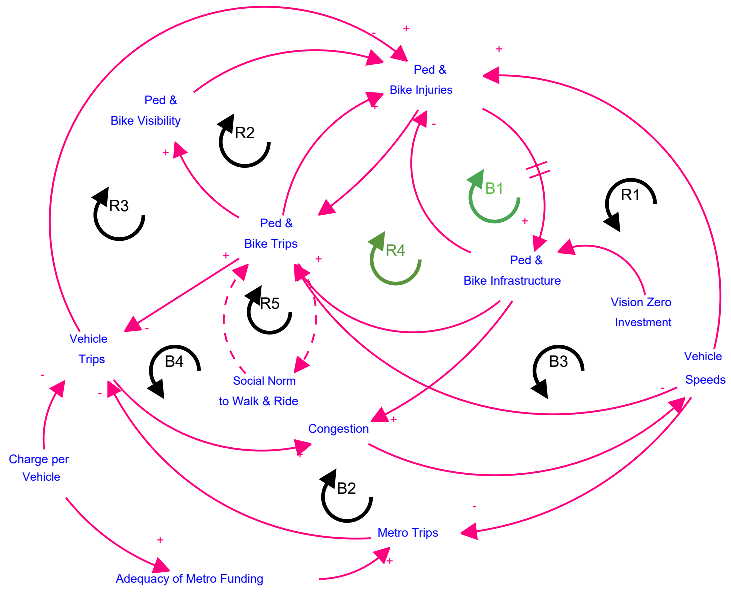
Creating a strong foundation of dynamic hypotheses (illustrated through a causal loop diagram)

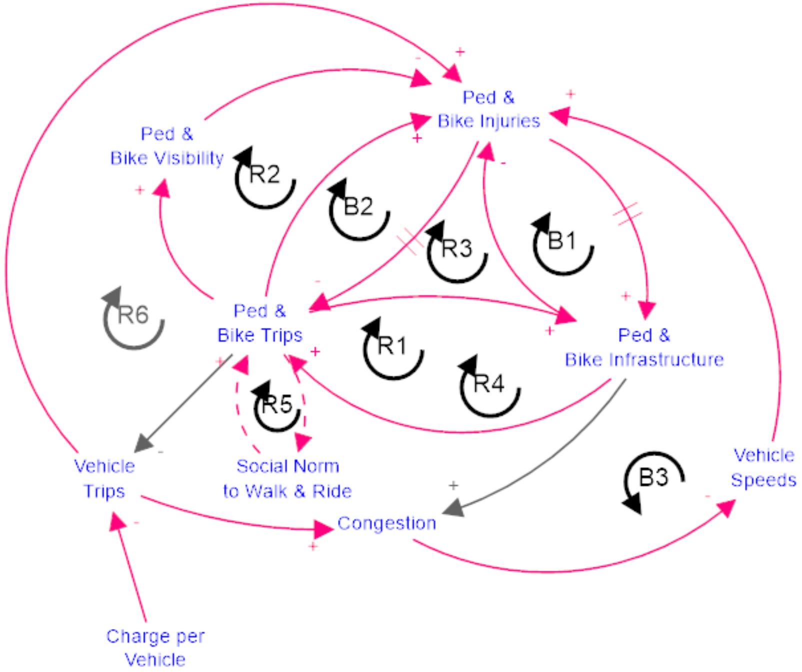
- Tailored the causal loop diagram to capture mechanisms believed to be strongest and most important for understanding pedestrian injuries over time in Manhattan
- Used an iterative process of systems-based interviewing (n=7), consulting with experts in pedestrian safety, engineering, planning, public health, and advocacy who were from academic institutions, the NYC Department of Transportation, and a NYC-based advocacy organization focused on vulnerable road users
- Asked interviewees to rank and discuss the likely impact of a range of specific feedback loops and dynamics on the overall pedestrian injury trend in Manhattan and set aside those believed to have little to no effect.
- Also solicited feedback on what else was missing
- Finalized within research team


Non-Discretionary Ped Trips
Vehicle Speed.
Pressure to Increase Road Capacity
Resources Allocated to Ped Safety
Ped Trips
Size of Region
Car Centric Culture
Pressure to Increase Road Capacity..
VMT
Congestion
Pressure to Address Ped Safety
Effectiveness of Ped Infrastructure
Ped Infrastructure Coverage
Size of Region...
Ped Behavior Enforcement
Impaired/Distracted Peds
Enforcement Capacity
Substance Use
Community Affected
Road Capacity for Vehicles.
Driver Behavior Enforcement
Ped Exposure to Vehicles
Vehicle Speed
"Acceptable Fatalities"
Driver Yielding
Pedestrian Fatalities
Congestion.
Emergency Response Time
Vehicle Safety Feature Development
Pedestrian-Vehicle Crashes
Ped Safety Focused Laws
Vehicle Dimensions
Size of Region.
Substance Use.
Enforcement Capacity.
Distracted Driving
Perceived Attentiveness
R1
R2
R3
R4
R5
R6
R7
R8 & 9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11
B12


Pedestrian Trips
Revenue from Public Transportation
Ped/Bike Injury and Death
Revenue Allocated for Maintenance
Trips Made Using Metro and Buses
Average Vehicle Speed
Ped/Bike Infrastructure
Average Travel Time of Vehicle Trip
Adequacy of Funding for Maintenance
Average Travel Time of a Metro/Bus Trip
Metro and Bus Fleet
Maintenance Required
Trips Made Using Vehicles
Congestion
Revenue from Congestion Pricing
Road Capacity
Trips Subject to Pricing
R1
R2
B1
B2
B3


Cyclist Injuries
Cyclist Visibility
Bike Trips
Cycling Infrastructure
Vehicle Trips
Congestion
Charge per Vehicle
Vehicle Speeds
Revenue for Public Transportation
Pedestrian Visibility
Pedestrian Infrastructure
Adequacy of Public Transportation
Pedestrian Injuries
Public Transportation Trips
Pedestrian Trips
R1
R2
R3
B1
B2
B3
B4
B5
B6


Ped & Bike Injuries
Ped & Bike Visibility
Ped & Bike Trips
Ped & Bike Infrastructure
Vision Zero Investment
Vehicle Trips
Social Norm to Walk & Ride
Vehicle Speeds
Congestion
Charge per Vehicle
Metro Trips
Adequacy of Metro Funding
R1
R2
R3
R4
R5
B1
B2
B3
B4


Ped & Bike Injuries
Ped & Bike Visibility
Ped & Bike Trips
Ped & Bike Infrastructure
Vehicle Trips
Social Norm to Walk & Ride
Vehicle Speeds
Congestion
Charge per Vehicle
R1
R2
R3
R4
R5
R6
B1
B2
B3

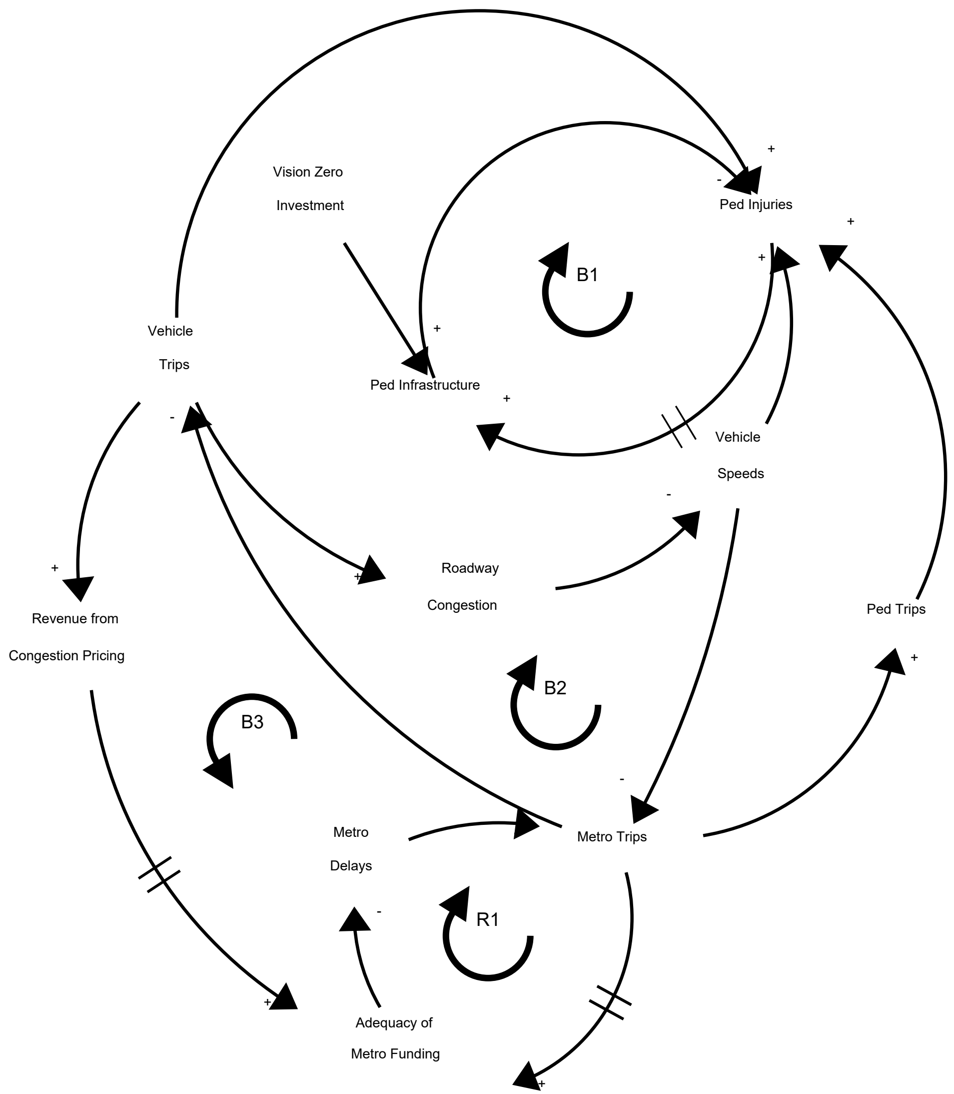


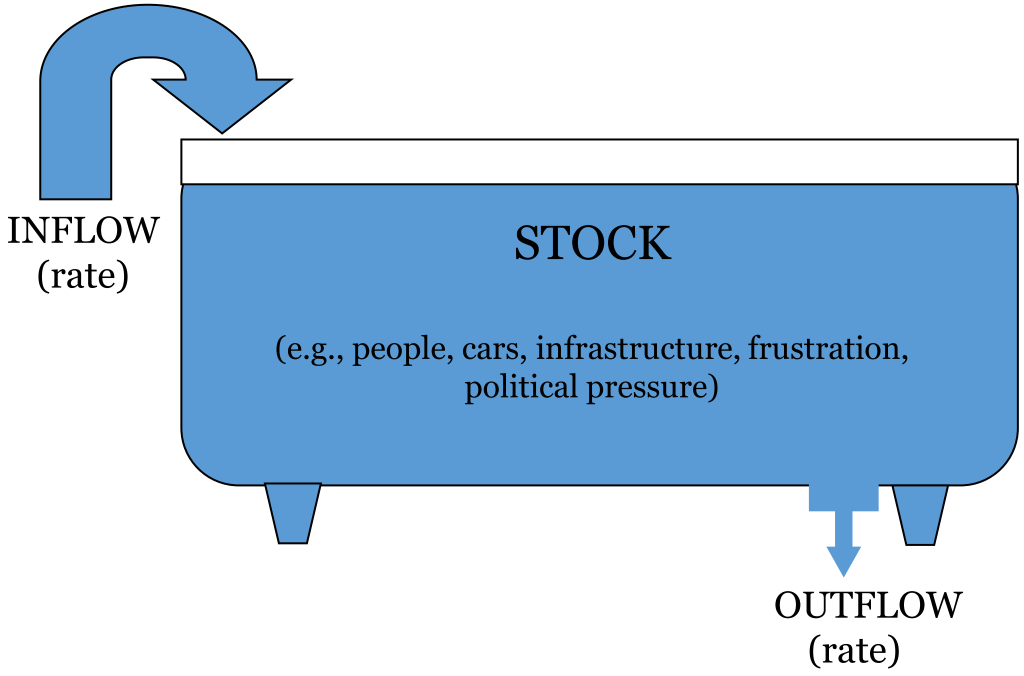
FIGURE. Causal loop diagram of feedback structure contributing to potential congestion pricing policy impacts on pedestrian injury

Arrows with a "+" sign indicate that a change in the originating variable leads to a change in the destination variable in the same direction (e.g., more vehicle trips leads to more congestion or less vehicle trips leads to less congestion), all else held equal. Arrows with a "-" sign indicate that the two variables change in opposite directions (e.g., more pedestrian infrastructure leads to fewer pedestrian injuries or less pedestrian infrastructure leads to more pedestrian injuries), all else held equal. R: reinforcing feedback loop; B: balancing feedback loop.

Causal Loop Diagram ⟶ Stock and Flow Simulation Model

- Stocks: where systems hold "stuff"
  - Give a system inertia, can be a source of delays, can be basis for action
- Flows: changes in stocks over time
  - Stocks can only change through their flows
  - Rates ("stuff" per unit time)
- Auxiliary/converter variables: functions of stocks and flows
  - Help define stock and flow equations

- Understanding how stocks and flows interact is not intuitive - It's not easy! Simulation can help
- Nonlinearity: the behavior of the whole is more than the sum of the behaviors of individual parts
  - Can not understand "emergent" behavior from the behavior of each individual piece

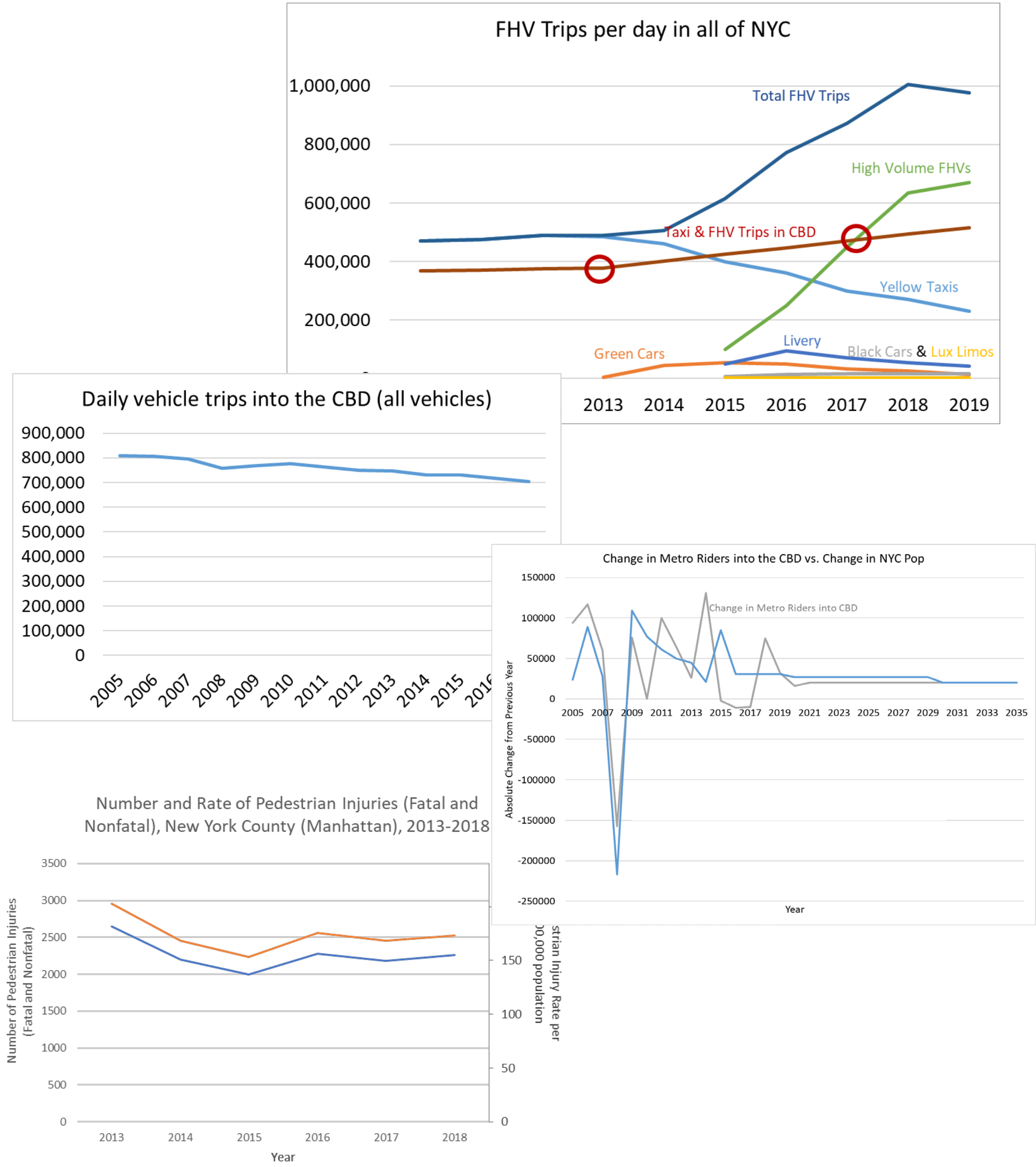


System dynamics simulation model construction

- Slow build up feedback loop by feedback loop with many tests (e.g., extreme conditions, variation in functional form describing relationships between variables)
- Acquire as much of information and data points as possible to validate and increase confidence (does it sit well in past data?)

What kinds of data?

- Pedestrian crash and injury data from the Department of Motor Vehicles Accident Information System through the NY State Traffic Safety Statistical Repository
- Several measures tracked through annual NYC Mobility Surveys and Reports, including data on average travel speeds in the central business district, vehicle trips into the central business district, transit ridership trends, and proportions of trips that are made by walking and other modes
- Population data from the U.S. Census and American Community Survey
- Freight vehicle data from the NYC Department of Transportation
- Taxi and for-hire vehicle trend data from the NYC Taxi and Limousine Commission
- Intersection count data from the NYC Pedestrian Safety Action Plan
- NYC Metropolitan Transportation Authority (MTA) data on transit ridership, expenditures and deficits, and average numbers of major delays on transit lines
- Detailed literature reviews were used to help define the functional form of relationships between key variables (e.g., speed and injury risk)



System dynamics simulation model construction

- Slow build up feedback loop by feedback loop with many tests (e.g., extreme conditions, variation in functional form describing relationships between variables)
- Acquire as much of information and data points as possible to validate and increase confidence (does it sit well in past data?)
- Calibration to observed data and policy tests
- Sensitivity analyses (particularly around unknown variables)

- **Purpose of the model is to serve as a learning model to explore congestion pricing impacts on pedestrian safety that can illustrate key insights about congestion pricing dynamics and the system dynamics approach**

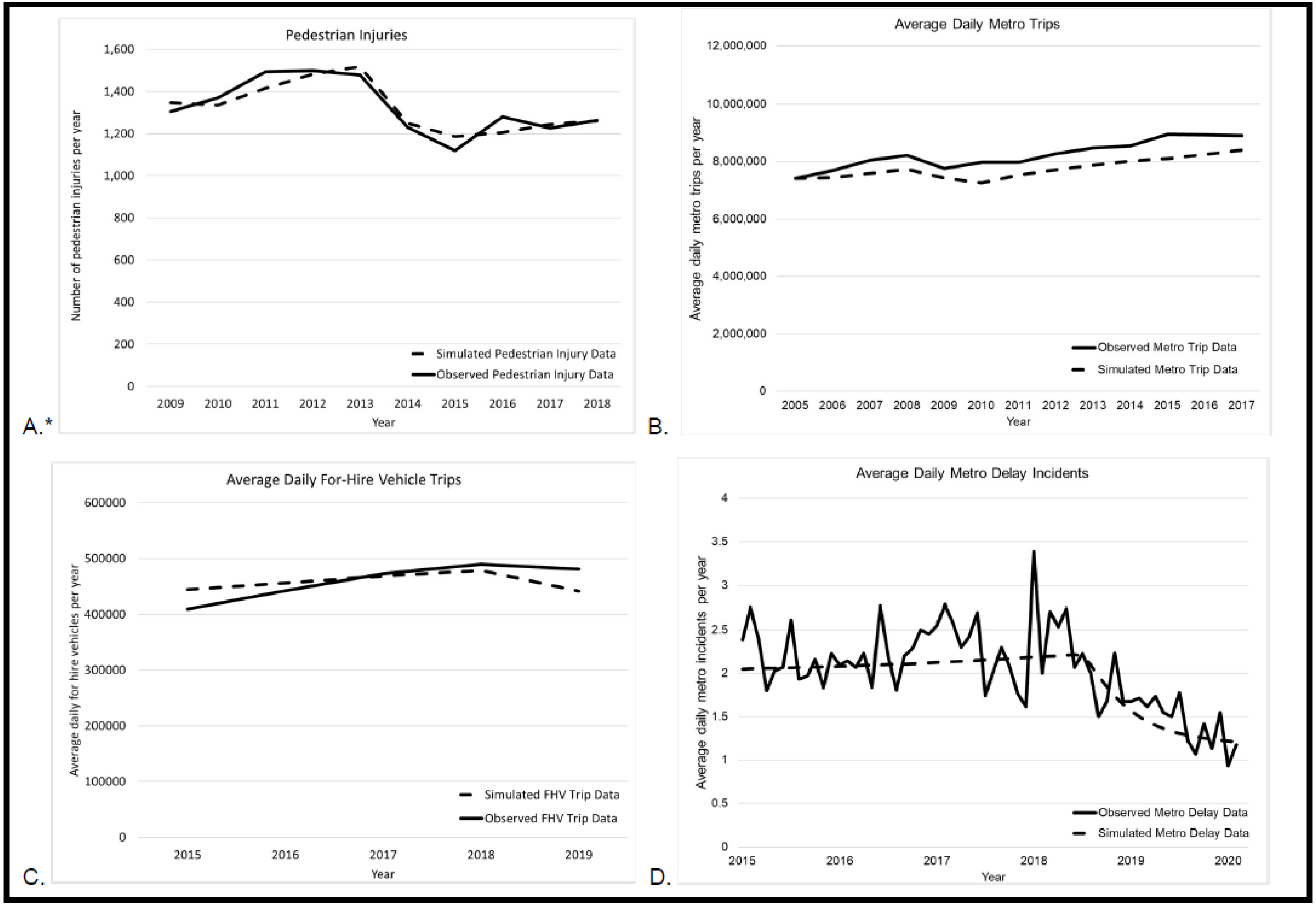


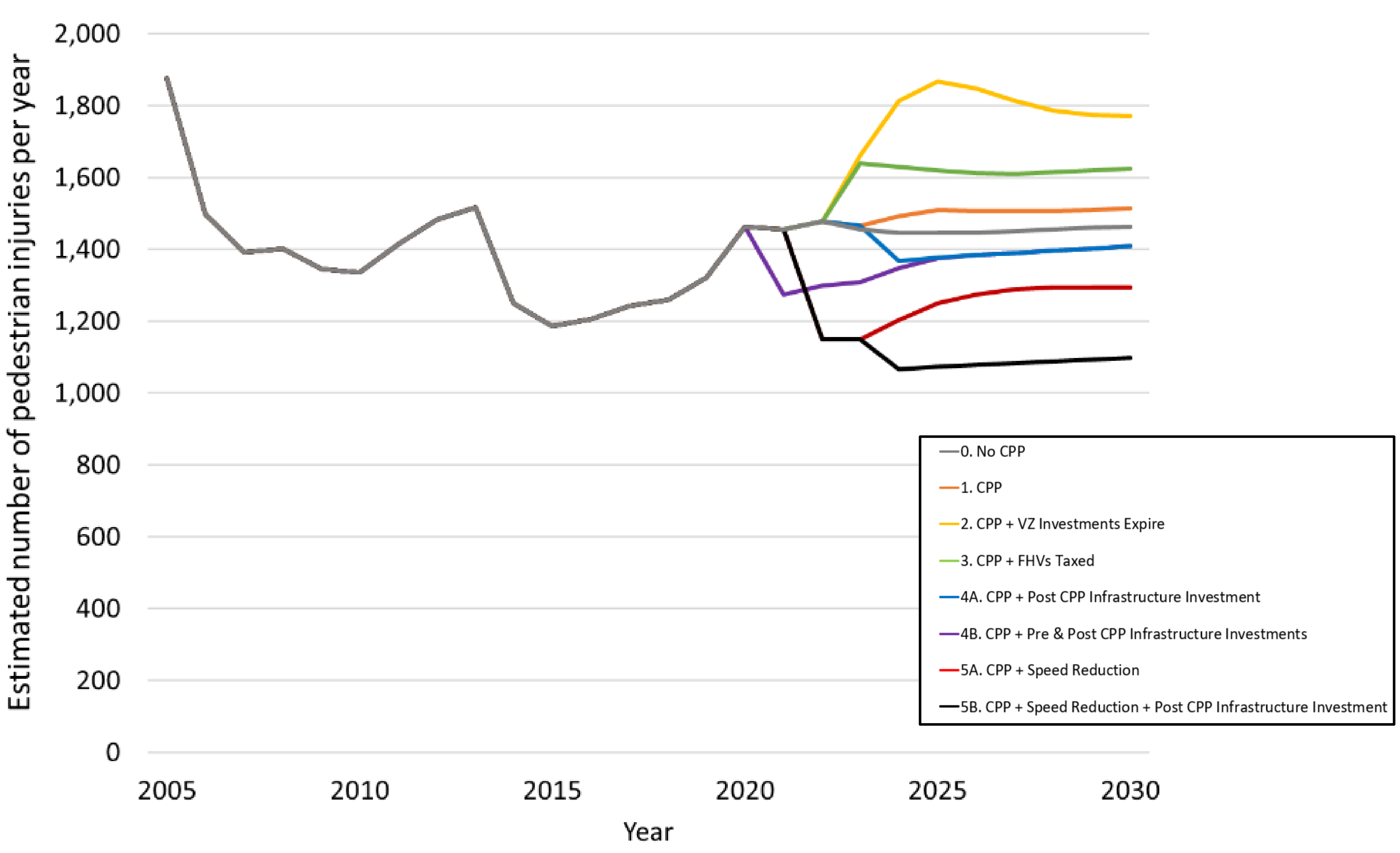
FIGURE 2. Observed vs. simulated data in congestion pricing policy-related system dynamics model

Simulated congestion pricing policy scenarios and intervention combinations

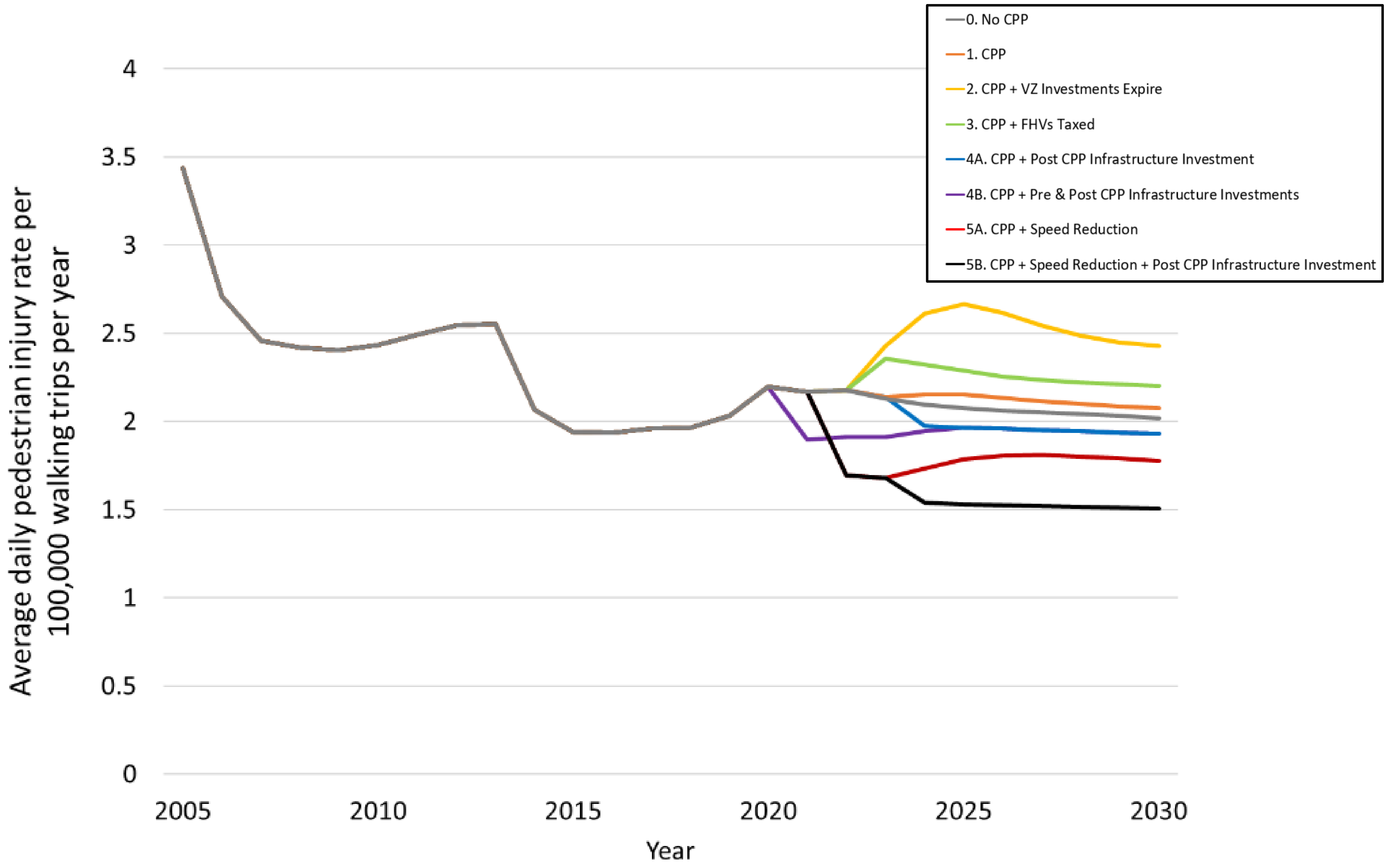
Simulated Policy Abbreviation	Simulated Policy Details*
0. CPP not implemented	No CPP implemented but Vision Zero (VZ) investments remain in place and unchanged.
1. CPP implemented and no other changes in policy	CPP implemented, assuming a $6 charge in each direction for vehicles entering and exiting the congestion pricing zone, beginning in 2022. We assumed for-hire vehicles are not charged under the new CPP. However, they are charged under a previous congestion-related surcharge placed on these vehicles, beginning in 2019. All revenue from the CPP is used to improve the metro system. VZ investments remain in place and unchanged. Assumes that none of the other policy options listed in this table are implemented.
2. CPP implemented and VZ investments expire	CPP implemented. Assumes consistent investments in improved pedestrian infrastructure which began when NYC adopted VZ in 2014. However, this scenario assumes that political will for VZ-related investments wanes, and while the CPP is implemented, the VZ investments for improving pedestrian infrastructure are removed at the time the CPP is implemented.
3. CPP implemented and FHVs taxed	CPP implemented and additional taxes placed on FHVs when the CPP begins. The model includes the FHV surcharge placed on these vehicles to mitigate congestion beginning in 2019. This policy scenario assumes that another tax (about $2.75 per FHV trip) is placed on FHV trips when the CPP goes into effect, in an attempt to further reduce congestion.
4A. CPP implemented and post CPP infrastructure investments funded by CPP	CPP implemented and a small proportion of CPP revenue is used to improve pedestrian infrastructure after CPP implementation, instead of all revenue feeding back into metro improvements. These investments are in addition to the standard VZ-related investments.
4B. CPP implemented and pre & post CPP infrastructure investments	CPP implemented and additional investments are made to improve pedestrian infrastructure after CPP implementation (like in 4A), as well as in the two years prior to CPP implementation, aiming to prepare for potential mode shifts. These investments are in addition to the standard VZ-related investments.
5A. CPP implemented with speed reduction	CPP implemented and measures put in place to keep speed consistently low post-CPP implementation, despite congestion being alleviated.
5B. CPP implemented with speed reduction & post CPP infrastructure investment funded by CPP	Essentially scenario 4A combined with 5A. CPP implemented; measures put in place to keep speed consistently low post-CPP implementation, despite congestion being alleviated; and a small proportion of CPP revenue is used to improve pedestrian infrastructure after CPP implementation, instead of all revenue feeding back into metro improvements.

CPP= congestion pricing policy; FHV= for-hire vehicle (such as Uber, Lyft); VZ= Vision Zero

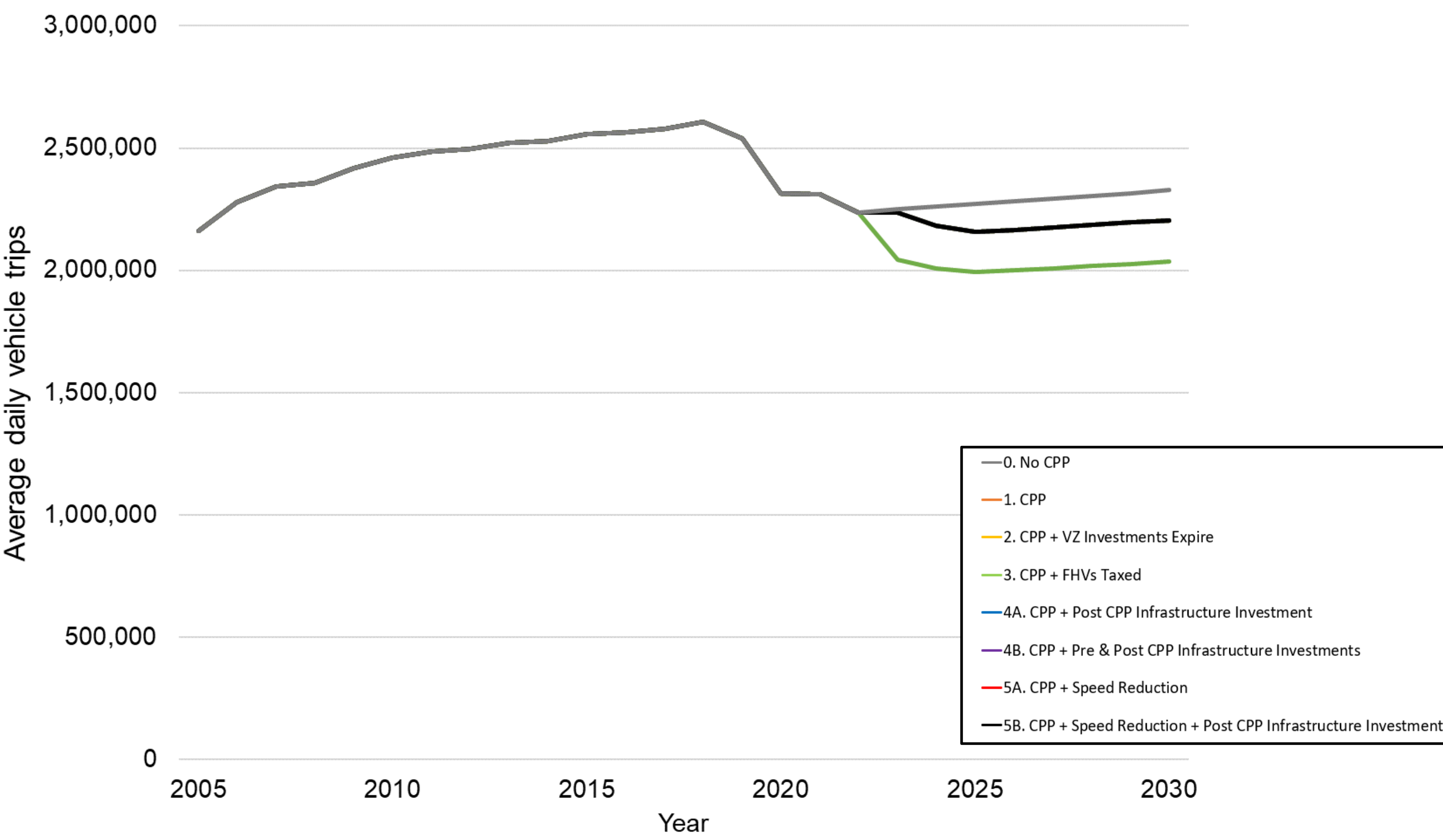
*All models, except for “Vision Zero investments expire post CPP” assume consistent investments in improved pedestrian infrastructure which began when NYC adopted Vision Zero (VZ) in 2014 and that these annual investments continue into the future (i.e., through 2030).



Estimated number of pedestrian injuries per year
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
2005
2010
2015
2020
2025
2030
Year
0. No CPP
1. CPP
2. CPP + VZ Investments Expire
3. CPP + FHVs Taxed
4A. CPP + Post CPP Infrastructure Investment
4B. CPP + Pre & Post CPP Infrastructure Investments
5A. CPP + Speed Reduction
5B. CPP + Speed Reduction + Post CPP Infrastructure Investment

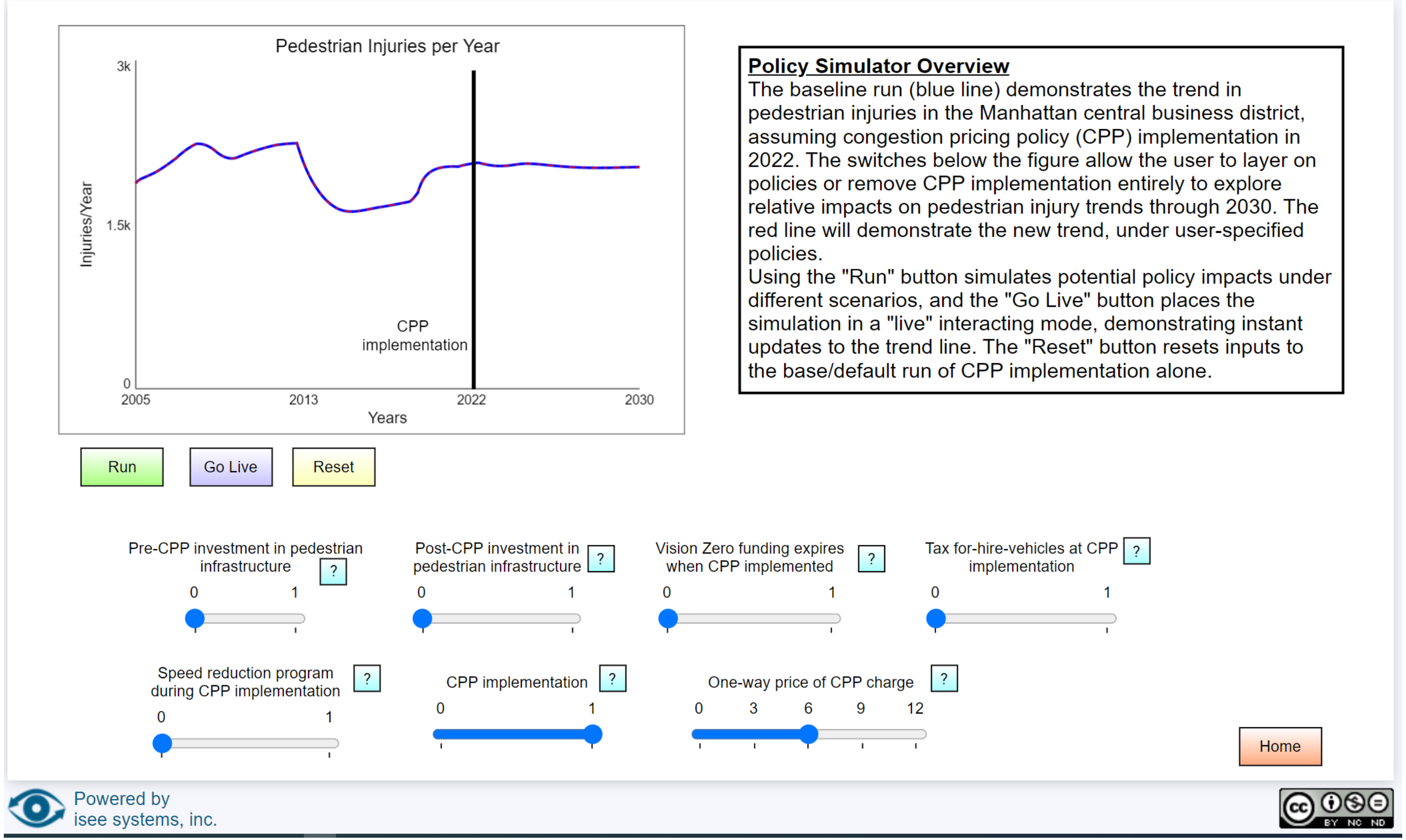


0. No CPP
1. CPP
2. CPP + VZ Investments Expire
3. CPP + FHVs Taxed
4A. CPP + Post CPP Infrastructure Investment
4B. CPP + Pre & Post CPP Infrastructure Investments
5A. CPP + Speed Reduction
5B. CPP + Speed Reduction + Post CPP Infrastructure Investment
Average daily pedestrian injury rate per 100,000 walking trips per year
4
3.5
3
2.5
2
1.5
1
0.5
0
2005
2010
2015
2020
2025
2030
Year



3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Average daily vehicle trips
2005
2010
2015
2020
2025
2030
Year
0. No CPP
1. CPP
2. CPP + VZ Investments Expire
3. CPP + FHVs Taxed
4A. CPP + Post CPP Infrastructure Investment
4B. CPP + Pre & Post CPP Infrastructure Investments
5A. CPP + Speed Reduction
5B. CPP + Speed Reduction + Post CPP Infrastructure Investment

A policy simulator to explore effects on pedestrian safety



https://exchange.iseesystems.com/public/beckynaumann/cpp-and-pedestrian-injury

Key takeaways

- Increasing interest over the last several years in CPPs, as major cities struggle with congestion-related impacts of car dependency, including reduced air quality, increases in obesity and other physical health concerns, and reduced quality of life from time spent on progressively congested roadways
- Absent from much of this research has been a focus on the safety of individuals traveling in and around these cities using different modes, despite worsening fatal and nonfatal injury trends, particularly for pedestrians
- Found that scenarios involving differences in how the CPP is configured and revenue is invested, and in congruent road safety interventions, resulted in similar congestion reductions (i.e., in average daily vehicles trips in the CPP area).
- However, considerable variation in the pedestrian injury trends by scenario type. Some scenarios had deleterious effects on pedestrian safety, while others offered notable improvements in pedestrian safety, in addition to limiting congestion.
- One important policy take-away from this work is that a CPP combined with other pedestrian efforts has substantial potential for positive gains in public health. On the other hand, adopting CPP and discontinuing infrastructure investments in safety could have a strong negative effect on pedestrian injury

For more information: Naumann RB, Sabounchi NS, Kuhlberg J, Singichetti B, Marshall SW, Hassmiller Lich K. **Simulation congestion pricing policy impacts on pedestrian safety using a system dynamics approach.** 2021. Under review at Accident Analysis and Prevention.

In summary, systems thinking approaches….

- Teach us to **think differently** about how systems behave (that is, in terms of dynamics, feedbacks, interactions)
- Allow stakeholders to **view the larger system** that a problem is embedded within and **strengthen dialogue** among stakeholders
- Foster development of rich, **hypotheses** that may be driving a persistent problem
- Provide a **framework for integrating** what we know, and determining importance of what we don’t know
- Offer a virtual world in which to **“try out” and compare** policies, examining potential **benefits and unintended consequences**