Collaborative Sciences Center for ROAD SAFETY

HOW-TO GUIDE

Causal Loop Diagramming How-To Guide

What is it?

- A diagram that clearly depicts how multiple factors in a system may interact to cause an outcome (e.g., road traffic crashes).
- Used to help better understand and disentangle the complexity surrounding specific problems or issues to inform action planning.

Why do we use it?

- To help understand a complex system from a variety of perspectives—to enrich our understanding of the factors working together to create problems.
- To identify "vicious cycles" are other circular relationships that perpetuate problems, or "virtuous cycles" that we can leverage to create beneficial change.
- To help identify and expand thinking on potential points of action (or "leverage points") within a system.

How to create a Causal Loop Diagram

There are several ways to approach causal loop diagramming, depending on the goals of the group and number of people involved. Several documents available from The Systems Thinker (www.thesystemsthinker.com) and [Scriptapedia]() can help provide additional step-by-step guides. Here we briefly discuss a very general framework that could be used to conduct causal loop diagramming:

1. Define the problem that you or your group is interested in understanding better. In other words, what is happening over time that you are concerned about (e.g., pedestrian deaths increasing)? Draw or plot this problem over time, using either real data or by approximating the trend.
2. Begin to brainstorm on important factors potentially related to this problem (e.g., related factors that may be changing over time)? These could be factors like changes in vehicle miles traveled over time, changes in vehicle size, changes in the impaired driving, etc.
3. Using these brainstormed factors, begin to build a causal loop diagram (or a "dynamic hypothesis") to help understand the factors that may be contributing to change in the core trend that you are concerned with (from step #1).

<u>To construct this causal loop diagram, use the following fundamental building blocks:</u>

- Variables: Important factors in the system. These factors can increase or decrease over time (e.g., vehicle trips).
- Arrows: Connections between variables, denoting that one variable is causally connected to another variable. (e.g., Crashes $\longrightarrow$ Injuries)
- Polarities: Notes the specific type of relationship between two causally connected variables. A "+" polarity or an "S" indicates that the two variables change in the same direction, all else held equal. A "-" polarity or an "O" indicates that the two variables change in the opposite direction, all else held equal.
  (e.g., Crashes $\xrightarrow{+}$ Injuries, or "more crashes lead to more injuries" and
  Safe walking infrastructure $\xrightarrow{-}$ Pedestrian crashes, or "more safe walking infrastructure leads to fewer pedestrian crashes").
- Feedback loops: Closed loops of causal connections that either reinforce change (a reinforcing loop) or resist change (a balancing loop). A reinforcing loop includes 0 or an even number of arrows with a "-" polarity, and a

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balancing loop includes an odd number of arrows with a "-" polarity. See the figure below for an example.

Using these building blocks, express stories and hypothesize about relationships between variables related to your core trend. Write your core variable (from Step 1) in the middle of your paper/board and consider the causes and consequences of change in that variable. Challenge yourself or others to consider the ripple effects of causal actions. Instead of stopping at X causes Y, ask but what does Y cause and does that turn back around to affect X?

Use variables, arrows, and polarities. When you identify a closed chain of connections (as shown in the figure below), label this as a feedback loop with a "B" for a balancing feedback loop or an "R" for a reinforcing feedback loop.

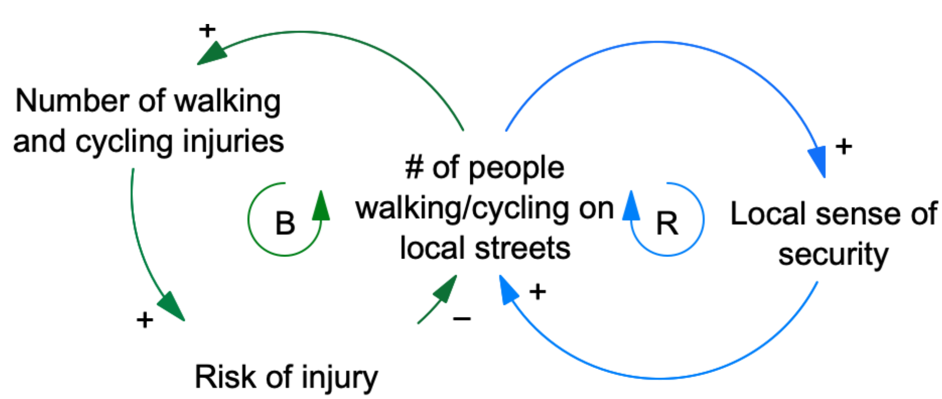
4. Using the diagram, you can begin to discuss your hypotheses about the factors interacting to cause your problem (and perhaps use it as a forum to discuss competing hypotheses within your group). The diagram should also be used as tool to expand thinking about potential opportunities for action.

These diagrams can inspire discussion:

- With this larger perspective of the system, ask partners to think carefully about actions (approximately 3) that they feel are most important to consider?
    - Consider consulting the Levels of Leverage framework to support brainstorming on impactful actions (see: https://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/)

- Recognizing that different partners touch different pieces of the system, challenge partners to consider which actions they could work on at this point? And given connections to other system elements, with whom do they need to work to ensure efforts are successful?

Example reinforcing and balancing feedback loops



Collaborative Sciences Center for ROAD SAFETY

CASE STUDY

Causal Loop Diagramming Case Study:

A Participatory Systems Thinking Tool to Understand Interconnected Factors that Affect Transportation Safety and Inspire Collective Action

Finding solutions to complex problems (such as traffic injuries and deaths) requires multi-stakeholder collaboration, including community members, advocacy groups, government agencies, and research institutions. Furthermore, to inform unified action, collaborating stakeholders need to develop a shared understanding of the set of interconnected factors (i.e., the “system") that contribute to the problem. However, both cooperation and the creation of a common view of issues at hand can be challenging. Different stakeholders have different priorities. They also have different levels of resources and views about the nature and causes of the problem. Moreover, there is often disagreement regarding the adequacy and feasibility of different solutions.

In this context, participatory systems thinking tools, like group-based Causal Loop Diagramming, offer powerful approaches to develop a common understanding of the interconnected factors that affect complex problems and design solutions that leverage collective action.

What is a Causal Loop Diagram?

Causal Loop Diagrams (CLD) are visual aids that show how multiple components of a system are interrelated and interact to cause a certain problem. CLDs are often drawn collaboratively as part of a group activity to help develop a shared understanding of how system components interact to drive observed trends.

CLDs include four key elements: variables, arrows, polarities, and feedback loops. **Variables** are nouns or short phrases that represent system components or factors that can go up or down over time. For example, in the context of safe and active transportation, walking and cycling injuries or traffic density might be important variables of interest that can increase or decrease over time.

In CLDs, variables are connected by **arrows.** The directions of the arrows are important. An arrow going from variable A to variable B indicates that a change in variable A causes a change in variable B (and not the other way round). For instance, an increase in traffic density will cause more pollution, but increased pollution will not necessarily lead to more traffic.

Another important characteristic of the arrows in a CLD is their **polarity.** The polarity of an arrow represents the nature of the relationship between the two variables connected by that arrow. A positive polarity indicates that the two variables move in the *same* direction. For example, in the diagram on the next page, we can observe that when the “local sense of security” in a community goes up, the number of pedestrians/cyclists goes up (or when the “local sense of security” goes down, pedestrian and cyclist activity goes down). In contrast, a negative polarity represents the opposite scenario; the two variables move in the *opposite* direction (e.g., an increase in injury risk leads to a decrease in the number of pedestrians/cyclists or a decrease in injury risk leads to an increase in pedestrian/cyclist activity). Usually, a “+” sign or an “S” (i.e., same direction) is used to denote a positive polarity, while a negative polarity is represented by a “-“ sign or an “O” (i.e., opposite direction).

Lastly, in a CLD, variables can form **loops.** This occurs when a series of interconnected arrows starting at one variable eventually leads back to this initial variable (see the diagram on the next page). Feedback loops can be *reinforcing (R)* or *balancing (B)*. Reinforcing loops produce virtuous or vicious

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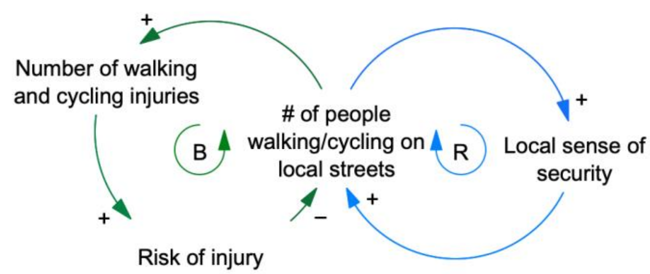
cycles (i.e., an initial change in any variable within the loop leads to changes in the same direction in that same variable, all else held equal). For example, in the hypothetical example diagram below, if more people start walking/cycling, other potential residents will have a greater sense of security and might start walking/cycling too, reinforcing that behavior. In contrast, balancing loops resist change (i.e., an initial change in a variable leads to a compensating change in the opposite direction in that variable). For instance, in the figure below, we might hypothesize that an increase in the number of pedestrians/cyclists can lead to an increase in the number of injuries, leading to an increase in perceived (and real) risk. This could, in turn, lead to a decrease in local walking/cycling, all else held equal.

Basic Structure of a Causal Loop Diagram



Why are CLDs helpful?

Because they are usually completed as part of a group activity, CLDs support development of a shared understanding of the most important factors governing the dynamics of the system or problem under study. In addition, through multi-stakeholder discussion, they can assist in the discovery of important perspectives that had not previously been considered or potentially important factors that might not be measured in research.

CLDs can also help us identify loops that should be supported to promote sustainability in beneficial outcomes. For instance, based on the diagram above, we might want to think of ways to foster a local sense of security that keeps that reinforcing loop activated and results in a sustained increase in local cycling and walking.

Finally, and relatedly, CLDs make it easier to discuss the potential impacts and unintended consequences of proposed interventions. For example, a short-term media campaign to increase local walking and cycling might initially increase the number of people walking/cycling on local the streets. However, in the absence of infrastructure improvements and other changes (e.g., speed management), it might lead to an increase in injuries and fear of cycling/walking in the area, which could hinder future active transportation efforts.

Real World Example

We used causal loop diagramming during a virtual workshop with organizations working to reduce child and youth pedestrian crashes and deaths in a large metropolitan area in the northeastern United States. These organizations (which included state planners, engineers, and community-based advocacy groups) had been collaborating for some time on Vision Zero efforts in the city. With a persistent and tragic problem of child and youth pedestrian injuries in their city, they specifically sought to come together to better understand contributing factors and mechanisms driving the problem, as well as to begin discussions around potential collective action that could be taken to increase their collective impact. Below, we describe how CLDs contributed to achieving these objectives.

CLDs in Action

We started the workshop with a brief introduction to systems thinking. We explained how systems thinking can help us better understand complexity and system behavior and facilitate cross-sector collaboration. We then introduced CLDs as a participatory systems thinking tool that facilitates stakeholder collaboration to develop a shared understanding of the dynamics driving a particular problem.

Informed by recent data analyses on contributing factors to child pedestrian injury in their city (and due to time constraints), we entered the workshop with an initial CLD, or “seed structure” for the diagram. We walked through the components of a CLD and the initial diagram that had been developed by the facilitation team as a starting point for discussion.

Using Miro (although several other tools, including Google’s Jamboard, Mural, Zoom’s whiteboard functionality could also be used), we marked up the diagram and took notes on the discussion, grouping themes. We specifically asked participants, what was missing, what was incorrect, and what should be removed. Using this discussion, the CLD was then iterated, updated, and reflected back to the group once more for additional edits. A QR code that links to a downloadable version of the final, simplified CLD and an overview of the process and key findings is included below.

What Did the CLD Reveal?

Drawing and refining the CLD together enabled participants to explore the different factors affecting child and youth pedestrian injuries at the local level, as well as the interconnections between them. For example, the CLD shed light on how a car dominant culture directly contributes to increasing the number of injuries by promoting more vehicle use and higher speeds and decreasing the likelihood of drivers stopping for pedestrians. It also illustrated how this culture indirectly affects injuries by decreasing political incentives for investments in safer pedestrian infrastructure. Furthermore, participants revealed how the interconnections between variables formed feedback loops. For example, one feedback loop identified was how the increase in the number of injuries leads to a decrease in community trust in the government, which in turn hinders community involvement in efforts around pedestrian infrastructure improvements, leading to more injuries over time.

After having the opportunity to reflect on the diagram as a group, participants were asked to identify the variables that may have the greatest impact on the dynamics of the system (and therefore the greatest potential as intervention targets). Attendees ranked **speed, roadway design, and pedestrian infrastructure** as the biggest contributors to child and youth pedestrian injuries. In parallel, **focusing resources on marginalized communities, outreach to co-create community change around transportation safety, and traffic calming and roadway design improvements to reduce speed** were seen as key actions that could be taken to reduce injuries and that could also potentially build off of efforts that participants had been engaged in.

Because speed was perceived as both a key influencing variable and a feasible target for intervention, we decided to delve deeper into how a potential speed reduction intervention would affect (and be affected by) the wider system. To do that, we constructed the simplified CLD shown below. In this diagram, we can observe that **community buy-in** and attention to **wider community issues like government distrust, general safety, and gentrification fears** (which in turn affect buy-in) are essential to increasing the effect of a speed reduction intervention. This is due to two reasons. First, community buy-in is necessary to deactivate the reinforcing "car-centered culture" loop on the left side of the diagram, which acts to hinder speed reduction efforts. Secondly, if wider community issues are ignored, community buy-in will decrease even if previous community-led interventions had contributed to decreasing injuries. Therefore, continuous activation of the "community trust" loop to support speed management efforts will require efforts to authentically gain community support.

Conclusions and Next Steps

CLDs are a powerful tool to facilitate group understanding and discussion of complex systems. The diagrams drawn during this session not only helped facilitate a common understanding of the mechanisms driving child and youth pedestrian injuries, but can also allow stakeholders, and the wider community, discuss and explore the effects (and unintended consequences) of potential solutions. This can, in turn, help ensure that strategies are collectively selected and designed to maximize impact.

Example Causal Loop Diagram focused on speed and speed-related intervention