Published in final edited form as:

Curr Epidemiol Rep. 2020 ; 7(4): 343–351. doi:10.1007/s40471-020-00248-z.

Systems thinking in the context of road safety: Can systems tools help us realize a true "Safe Systems" approach?

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Abstract

Purpose of review: Road traffic injuries are one of the leading causes of death in the U.S. and globally. We introduce the Safe Systems approach as a promising paradigm for road safety practice and describe how systems thinking tools can help bridge the gap between the current status quo and a Safe Systems approach.

Recent findings: Systems thinking tools can help us align with a Safe Systems approach by identifying latent risks in the transportation system, examining factors that coalesce to produce high travel speeds and kinetic energy transfer, and supporting safety prioritization through goal alignment.

Summary: The Safe Systems approach represents a significant change in the way we have historically designed transportation systems; it puts safety at the forefront and calls for designing a system that accounts for human fallibility. Operationalizing holistic Safe Systems concepts may be difficult, but systems thinking tools can help. Systems thinking tools provide a common language for individuals from diverse disciplines and sectors to express their unique understanding of the interconnected factors shaping road safety problems and support discussions about potential solutions that align with a Safe Systems approach.

Keywords

road safety; transportation; Safe Systems; systems thinking; causal loop diagram; injury prevention

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Conflict of Interest: The authors report grants from U.S. Department of Transportation, North Carolina Governor's Highway Safety Program, and Federal Highway Administration during the conduct of the study.

Human and Animal Rights and Informed Consent: This article does not contain any studies with human or animal subjects performed by any of the authors.

INTRODUCTION

Globally, road traffic injuries cause more than 1.3 million deaths annually and are the leading cause of death for children and young adults (ages 5–29 years) [1]. While some countries have made progress in reducing deaths over the last several years, many continue to observe either a stagnant or steadily increasing trend in casualties [1]. In the U.S., traffic death rates have plateaued, with crashes killing more than 35,000 people each year, and pedestrian deaths have reached a thirty-year high [2]. The magnitude and persistence of this public health problem underscores the need for a new approach to road safety practice. A Safe Systems approach holds promise for delivering enormous safety benefits, and adoption in other countries has shown success [3–6].

In this paper, we introduce a Safe Systems approach as a means to significantly improve road safety and injury prevention practice, summarizing the core principles of the approach and detailing how the approach differs from much of current practice. We also describe why and how systems thinking, an interdisciplinary field focused on understanding complex systems (like systems underlying road traffic injury) and improving collaborative and strategic action, is uniquely equipped to help us implement Safe Systems concepts and methods.

CURRENT STATE OF ROAD SAFETY PRACTICE

Modern road safety practice is perhaps best understood by examining its organizing assumptions, means of attributing causality in crashes, and actions based on this causal understanding. To illustrate these facets, we draw on examples involving vehicle speed and related crashes and injuries, as a thread for our examination.

Arguably, one of the dominant organizing assumptions surrounding crash causation in the U.S. is *safety individualism*. Akin to "health individualism," which attributes health outcomes to individuals' choices while neglecting the larger context and social determinants of health [7], "safety individualism" similarly ignores the larger context and network of factors from which traffic injury arises. For example, speed-involved collisions, while partially determined by individuals' behaviors, are largely informed by the road design and driving context [6, 8]. And, the road design and context is largely a product of legacy decisions, or past transportation infrastructure decisions that have produced road-land use environments which serve incompatible goals (e.g., higher speed vehicle travel on the one hand and pedestrian and bicyclist access on the other) [6, 8]. However, these factors are often ignored in the way we report and classify crashes [9].

Another prevailing assumption in road safety practice is a common belief and overreliance on the *transferability* of studied safety interventions [10]. Such linear, cause-effect assumptions lead road safety practitioners to believe an intervention with proven effectiveness in one context will be equally effective in another context, and that effectiveness will often be sustained. For example, consider the use of high-visibility enforcement to reduce speeding. Although the City of San Francisco recorded substantial speed reductions following the implementation of a high-visibility speed enforcement program, within only one week of the program's cessation, driver speeds returned to pre-enforcement levels [11]. Human behavior regularly demonstrates dynamic change because of the broader social and cultural conditions that interact to influence such behavior [12].

A third predominant mindset, which follows from the two above, relates to the siloed nature of both understanding and addressing road traffic injuries, using the "Es" framework [13]. The Es (i.e., traditionally Engineering, Education, and Enforcement) have prevailed in road safety since the 1920s [14, 15]. Engineers have historically been trained to design roadways to accommodate high travel speeds. Education has involved teaching drivers how to responsibly operate automobiles and obey speed limits, and enforcement has targeted drivers and pedestrians who were characterized as reckless or irresponsible. To this day, states and cities across the U.S. advance road safety initiatives that evoke the Es, or otherwise compartmentalize traffic safety problems into discrete issue packages, e.g., "safer streets" (engineering), "safer people" (education and enforcement), and "safer vehicles" (vehicle design) [16].

Conceptually, the Es of traffic safety require drawing a straight line between cause (usually individual road user behavior) and effect (traffic injury), and working within discrete categories of interventions with "known" transferrable effects. Yet as social change scholars have argued, new approaches are needed that move away from thinking of cause-and-effect as siloed determinate inputs and outputs, and toward approaches that recognize complex relationships between factors that produce effects [17–19]. As such, we argue that the Es framework is limited to the extent that it fails to contend with the socio-ecological dynamics at the root of traffic injury and that determine the effectiveness of interventions seeking to reduce injuries. Thus, in order to step down from the current traffic fatality plateau [20], road safety practice must evolve. This evolution will require a paradigm shift in how the causes of road injury are determined and the ways in which multi-faceted, integrated solutions are developed and implemented [3–6, 21].

A PARADIGM SHIFT: THE SAFE SYSTEMS APPROACH

Beginning in the 1990s, Sweden and the Netherlands led a complete paradigm shift in road safety. Sweden's Vision Zero and the Netherlands' Sustainable Safety focused on Safe Systems, an approach that put safety at the forefront and called for designing roadway systems that account for human fallibility [3–6, 21]. These efforts have led to impressive results in overall and vulnerable road user-specific fatality rates. Since then, a few other countries, such as New Zealand and Australia, have followed suit in adopting road safety approaches based on Safe Systems [4, 5, 21].

Safe Systems hinges upon a key consideration: our transportation system must be one in which road users will not perish, regardless of potential "human errors" [3–6, 21]. Under this guiding principle, transportation system managers, vehicle manufacturers, law enforcement officers, land use planners, and roadway users are all responsible for mitigating risk of death or serious injury on the roadway, not as individuals, but as interconnected stakeholders operating within the same system.

Although practitioners and proponents of Safe Systems subdivide the guiding principles into a varying number of subprinciples and pillars (see, for example, [22]), the key components can typically be summarized in four concepts: 1) accommodate and adapt to human behavior; 2) recognize the role of speed and energy transfer; 3) prioritize safety; and 4) strengthen all parts of the system. Below, we survey each of these four principles, demonstrating how Safe Systems is an important paradigm shift for road safety management and how it diverges from much of current practice.

I. Accommodate and adapt to human behavior.

The traveling task, whether operating a vehicle at high speed or selecting an appropriate time and location for crossing a busy street, places substantial cognitive load on road users to navigate numerous potential conflicts where speeds may be life-threatening [23, 24]. A key difference between Safe Systems and previous road safety management paradigms is the acknowledgment that mistakes are rarely outcomes of active failure but instead are produced by latent error designed into the system[25]. Put differently, “road crashes are seen as a consequence of latent failures created by decisions and actions within the broader organizational, social, or political system which establishes the context in which road users act.” (p.27, [4]).

Due to the latent risks inherent within the roadway system, a Safe System requires safeguards and designs to account for the eventual lapse in focus, loss of attention, or misjudgment while traveling on the roadway. A key consideration is the mitigation of kinetic energy transfer in the event of a crash, which requires system designers to build in safety nets that reduce potential harm. There are numerous examples of this principle applied in practice (as shown in Table 1) and a large body of human factors and behavioral science literature, which inform system level actions in policy, land use, and roadway design that account for inevitable human error.

II. Recognize the role of speed and energy transfer.

Speed is linked not just to the frequency of crashes but also the severity [26], due to the kinetic energy transferred to the human body upon collision. The likelihood of a fatality for an unprotected road user increases significantly when speeds exceed 20 miles per hour (mph). At 50 mph, a car striking a pedestrian has a 75 percent chance of killing that pedestrian [27]. High motor vehicle speeds can reduce gaps in traffic, limiting safe crossing opportunities and make identifying such opportunities more difficult [24].

Although the Es acknowledge the causal role of speed in crashes, the siloed Es approach places kinetic energy management in the realm of enforcement (i.e., setting and enforcing speed limits), rather than addressing the built environment context that produces deadly combinations of speed and collision angles. In a Safe System, stakeholders are chiefly concerned with the contributory factors that align to produce kinetic energy above human tolerance, rather than just the speed limit itself [6]. Adopting this holistic perspective can lead specifically to innovative intersection designs [28], and more broadly to better land use and roadway function integration that accounts for the presence of different road users.

III. Prioritize Safety.

The third principle of Safe Systems is often typified as "prioritizing safety," and on first look may seem to be a natural extension of the existing Es paradigm. However, this concept is more than just a simple affirmation of the work conducted under engineering, enforcement, and education. Truly prioritizing safety may require difficult decisions regarding project prioritization and a recognition that some mobility – though not all – may be sacrificed to provide the safety net required by the first principle of Safe Systems.

To distinguish between a traditional approach and Safe Systems, consider speed limit setting. Especially in rural road contexts, speed limit decisions are commonly made based on the 85^{th} percentile, or the speed at or below 85% of all vehicles are observed to travel under free-flowing traffic conditions [29]. However, as we previously illustrated in the discussion of kinetic energy, nominally efficient speed limits frequently exceed human crash thresholds. A true prioritization of safety requires consideration of broader community needs and road functional considerations (e.g., cyclist access) and may result in lower speed limits to facilitate greater harmony among different road users.

IV. Strengthen all parts of the system.

While the Es have thus far yielded significant improvements in road safety as siloed operations, they are unable to fulfill a Safe System. Many organizational and environmental factors influence road safety to create inherent risks within the system. Addressing these risks requires strengthening all interrelated components of the system. To do so, we must first understand the myriad ways injury risks propagate through the system.

This approach to risk management—similar to Reason's "Swiss Cheese" error model (2000)—is best illustrated with a hypothetical crash example [30]. Assume that a young driver is approaching an intersection at night on a wide, urban arterial road. The driver makes a quick right turn at the intersection and hits an unseen pedestrian crossing the street. While we can imagine individual countermeasures to address specific elements of this crash—e.g., improved roadway lighting or automated speed enforcement to reduce the kinetic energy in the crash—we may also strengthen the system by considering what factors led to both roadway users being in this type of conflict at this location at this time of day. Taking a system-level view may identify the need for better network connectivity throughout the city that would allow for a pedestrian route with minimal interaction with motor vehicles. This view may also call attention to the land use context and the need for narrower roadways that would condition the driver to operate a vehicle more slowly and to recognize an area where it is common to encounter pedestrians. To strengthen the system, we must first understand the system of interconnected factors at play.

BRIDGING THE GAP: HOW CAN SYSTEMS THINKING HELP?

To work towards a Safe System utilizing the principles outlined above, we first need to understand how stakeholders, roadway designs, practices, norms, and policies in our communities interact to produce or perpetuate the undesirable outcomes we currently observe over time. "Systems thinking" and systems tools can help us do this. They can help us understand latent risks in the transportation system (Safe Systems concept 1), examine factors aligning to produce high travel speeds and kinetic energy transfer (concept 2), prioritize safety through goal alignment (concept 3), identify where there might be weaknesses in the underlying system so that we can strengthen all parts of the system (concept 4), and support unified action forward.

Before we discuss what we mean by “systems thinking” and the types of tools that can help us, it is critical to have a common understanding of what we mean by the word “system.” According to Donella Meadows, a leader in systems thinking, a system is “an interconnected set of elements that is coherently organized in a way that achieves something.” (p.11, [31]). Systems exist all around us (e.g., a car, the human body, a metropolitan transit system), and all systems have a boundary within which exists all relevant, interacting components needed to produce a given outcome(s). While some boundaries may be easier to see, like in the examples of systems provided above, others, like the system producing crashes, can be harder to “see.” However, remaining focused on the outcome of concern, or as Meadows puts it, the “things achieved” by the system, we can begin to illuminate the relevant, interacting components producing that outcome [31]. If we want to reduce the outcome of speed-related crashes (or any other type of crashes), we need to elucidate the interconnected environmental, political, cultural, and behavioral elements that interact to bring about those crashes in the first place and learn how best to intervene and act within that system.

So, how do we illuminate the system of factors? We can use “systems thinking” and its related tools. Simply put, systems thinking, according to Peter Senge is “…a discipline for seeing wholes” [32], or more formally put, according to Arnold and Wade (2015), is “a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them in order to produce desired effects.” (p.675, [33]). Systems thinking accepts that complex problems, like speed-related crashes, cannot be understood by studying individual factors in isolation. Rather, as Ottino (2003) states: “The very essence of the system lies in the interaction between parts and the overall behaviour that emerges from the interactions. The system must be analysed as a whole.” (p. 293, [34]). As discussed in previous sections, there is a natural tendency for road safety professionals (and all humans for that matter!) to reduce and divide problems driven by complex systems of factors into smaller, more manageable components and to push harder on familiar approaches in isolation (e.g., the Es). However, the Safe Systems approach challenges and requires us to comprehensively consider the larger “whole.” With the help of systems thinking tools, this daunting task becomes more manageable.

A SYSTEM THINKER’S TOOLBOX

There are many tools within the system thinker’s toolbox, all with the common goal of helping us understand the interconnected components and interactions comprising complex systems and driving the persistent safety, health, and societal problems we grapple with on a daily basis. While it is beyond the scope of this paper to describe the universe of systems thinking tools and pertinent applications to road safety, we refer the interested reader to several foundational texts and papers in this space [35–52]. Below, we introduce two specific and complementary systems thinking tools as an introduction to the systems thinking toolbox: 1) the five Rs [53] and 2) system mapping (or causal loop diagramming) [35].

The Five Rs

The five Rs is a simple and practical systems thinking tool that was first introduced by the U.S. Agency for International Development (USAID) [53]. With their recognition that "achieving and sustaining development results depends on strengthening the local systems that produce those results," (p.2) USAID developed systems-related guidance and tools, such as the five Rs to help inform the design, implementation, and monitoring of projects and activities [53]. The five Rs help illuminate the broader system around an area of work and provide an efficient way for multidisciplinary groups of stakeholders operating within the same area to describe key features of the system, define meaningful measures, ensure engagement of all relevant stakeholders, and design systems action mindful of available resources, rules (i.e., constraints, norms, etc.), and key relationships.

Applying the five Rs means we are specifically trying to understand the Results, Roles, Resources, Relationships, and Rules embedded in the system with the ultimate goal of informing more effective action [53]. Using the five Rs may involve convening stakeholders, seeking diverse (including often marginalized) perspectives through interviews, and analyzing data of various types (e.g., public opinion surveys, injury surveillance system data, budget and policy-related documentation) to understand the current system. With a solid understanding of the current system, the five Rs can be further applied to capture a future "to be" system and brainstorm on mechanisms to achieve it, to select and design appropriate interventions, and to develop monitoring and evaluation plans. Below, we demonstrate how the Rs can clarify the current system, and we refer the interested reader to additional guidance on iteratively working through the Rs during subsequent project and initiative stages (e.g., intervention implementation and evaluation) [53].

1. A first step in applying the five Rs is to understand what stakeholders view as the most meaningful indicator(s) of success or the target **result(s)** around which the system is defined. Clearly defining and agreeing upon a focal result(s) can help align stakeholder goals, sets the boundary for the system being examined, and frames the discussion around the remaining Rs. In road safety, we are often most interested in reducing fatal and nonfatal injuries; our focal result may be overall, road user-specific (e.g., pedestrian injuries), or crash type-specific (e.g., speed-related crashes), depending on the scope of the project or initiative.

2. With a unifying factor (i.e., our target result(s)) around which to define the current system, a next step is to enumerate individuals and organizations with a **role** in the system. These include many of the usual roles we easily think about when talking about road safety—planners, law enforcement, travelers (e.g., drivers, pedestrians, cyclists), and engineers. However, systems thinking pushes us to explore the larger body of roles in the system generating crashes and injuries—roles like vehicle manufacturers; local, state, and national policymakers; mode-specific advocates; and social services working with marginalized and vulnerable populations, like homeless individuals.

3. **Resources** available to achieve results should also be clarified when taking a systems approach. These can include funding, people or time, specific skills or expertise, and programs—any resource that helps drive the system. Examples include the resources available to retrofit intersections or roadways in order to bring them in line with a Safe Systems approach, the training available for professionals on speed management best practice and concepts, and skilled communications specialists available to design and deliver media messaging consistent with Safe Systems principles.

4. A fourth “R”—**rules**—refers to both formal (e.g., mandates, regulations, laws) and informal (e.g., organizational practices, community norms) rules operating within the system. Of greatest interest are rules that relate to the other Rs, meaning the rules that determine who has a role in road safety, what resources are available and how they are to be used, and restrictions on which relationships can form. For example, rules around speed-related crashes, specifically, could involve land use planning regulations, speed limit norms, laws related to automated speed enforcement, funding allocation norms and rules, and speed-related vehicle regulations.

5. Finally, tightly linked to the roles, rules, and resources specified above are the key **relationships**. Relationships can be between individuals, between organizations, or between individuals/organizations and resources. Relationships may involve collaboration, information sharing, trust, and influence and can be characterized along a spectrum from mutually beneficial to destructive. To focus the relationships examined, we have found it most useful to begin with a consideration of the three to five most crucial relationships believed to affect the focal result. As an example, for speed-related crashes, these may involve relationships between the larger community (and their beliefs and norms around speed) and politicians (and the political pressures they perceive from those community members), law enforcement and the public (with relationships potentially varying between trust and distrust for different communities), and federal road safety funding agencies (and their regulations) and state departments of transportation.

Using the five Rs and working with diverse stakeholders to understand the current system generating a problematic outcome can serve several key purposes that support a Safe Systems approach. The five Rs enumeration process and synthesis can increase collaboration among partners, as they reinforce and identify their roles in the system and common goals; help partners recognize potential gaps in the system; identify the larger network of factors at play in driving the result(s) they care about; and pinpoint potential opportunities for change or system strengthening [53].

System Mapping and Causal Loop Diagramming

With an understanding of the broader system at play, guided by the five Rs, at times we need or want to go deeper to understand *how* the many enumerated factors interact to produce the outcomes or results we observe over time. Mental maps, also known as causal loop diagrams

(CLDs), help us depict the complex causal processes hypothesized to drive a result or outcome of interest [31, 35, 54]. They allow us to make our "mental models," or the way we think the world works, explicit in a form that is easy to communicate to others. Similar to the five Rs, CLDs are often constructed in a participatory and stakeholder-involved manner, using an approach called group model building, which involves building systems thinking capacity among groups of stakeholders so that they can help map the hypothesized mechanisms and interactions in a system [50].

CLDs, group model building, and the larger field they originate from termed system dynamics have a long history of success in helping researchers and practitioners illuminate mechanisms driving complex problems and leverage points for interventions [35, 36]. CLDs are made up of 1) variables and 2) arrows representing causal connections between variables. Circular chains of these variables and arrows form two fundamental CLD building blocks: reinforcing feedback loops and balancing feedback loops, which can be powerful drivers of change over time [35]. Reinforcing feedback loops are causal circular chains of factors wherein an increase (decrease) in one factor ripples through the chain to cause a further increase (decrease) in that factor (e.g., as more people become vehicle users, norms and attitudes favoring pro-vehicle policies increase, leading to more road capacity for vehicles and more vehicle users, all else held equal). In contrast, balancing loops are causal chains of factors wherein an increase (decrease) in one factor ripples through the chain to cause a decrease (increase) in that factor (e.g., as speeding increases, there may be an increase in enforcement of driving at high speeds and a decrease in speed (at least temporarily), all else held equal). There are several examples of CLDs, or diagrams of interwoven balancing and reinforcing feedback loops, used to explore and increase understanding of complex road safety systems [38–41, 43, 55]. CLDs and their collaborative construction provide a framework for transdisciplinary discussions, group learning, and influential conversations about strategies, such as Safe Systems strategies, most likely to optimize outcomes within the system.

In Figure 1, we provide an example of a simple map or CLD that could help aid a Safe Systems-informed discussion around vehicle speeds, sprawl, and crash risk. The CLD includes two balancing loops and a reinforcing loop. The first balancing loop (B1) depicts how a congestion problem might be addressed in many communities, showing that as vehicle congestion increases and vehicle speed decreases, the community pressure to increase the road network and capacity in the community increases. A subsequent increase in road network and capacity generally is perceived as "solving" the congestion problem for some period of time. However, this "solution" often diverts attention away from a more long-term and fundamental solution—i.e., the investment in infrastructure for safe and sustainable travel modes (e.g., transit, cycling, walking), shown in the second balancing loop (B2). The common fix of increasing the road network drives sprawl, which increases car dependency and inaccessibility of non-personal vehicle travel modes. This in turn decreases the pressure to invest in those non-personal vehicle travel modes. Moreover, as vehicle speeds increase due to congestion relief from larger and faster road networks, crash-related injuries increase, and as this "solution" undercuts pressure for investment in safe infrastructure for other modes (and makes it harder to implement infrastructure over wider distances), those that do need or want to walk and cycle are more exposed and vulnerable to crash risks. From a Safe Systems perspective, even this simplified diagram could inform important conversations about the role of speed and prioritization of safety (Safe Systems concepts 2 & 3), as opposed to other system goals (e.g., vehicle throughput).

Finally, there are numerous other tools, such as system support mapping, network mapping, and system dynamics simulation modeling, that can help improve our understanding of the interconnections, visualize the "whole," and guide decision-making on where and how best to intervene using a Safe Systems-informed approach [35, 49, 52, 56]. Simulation models are particularly advantageous for identifying points of leverage within a system and determining how intervening on different parts of the system, and in what order, might alter the road safety outcomes we would like to change [35, 49, 52, 56]. In sum, there are a variety of complementary systems tools that can help us articulate and understand the complex drivers of our persistent road safety problems and support a Safe Systems approach.

CONCLUSIONS

Road traffic injuries remain one of the leading causes of death in the U.S. [2]. The Safe Systems approach holds promise for delivering enormous road safety benefits, and adoption in other countries has shown success [3–5]. A Safe Systems approach requires that we shift current road safety practice to better accommodate and adapt to human behavior; recognize the critical role of speed and energy transfer; prioritize safety in all actions; and strengthen all parts of the system. Operationalizing this systemic and holistic approach to road safety can be difficult, but tools from systems thinking can help. Systems thinking tools provide a common language for individuals from diverse disciplines and sectors to express their unique understanding of the interconnected factors shaping road safety outcomes [31]. Using tools, like the five Rs and system mapping, we can begin to produce a unified and cohesive view of the problem, the multi-component factors and interactions underlying the problem, and the larger system we are working within. Systems thinking tools support rich discussions and analysis of potential solutions and how best to align and implement a Safe Systems approach.

ACKNOWLEDGEMENTS

Financial support for this work was provided by the Collaborative Sciences

Center for Road Safety (www.roadsafety.unc.edu), a U.S. Department of Transportation National University Transportation Center (Award No. 69A3551747113) and by the University of North Carolina at Chapel Hill Injury Prevention Research Center through an award (R49/CE0042479) from the Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.

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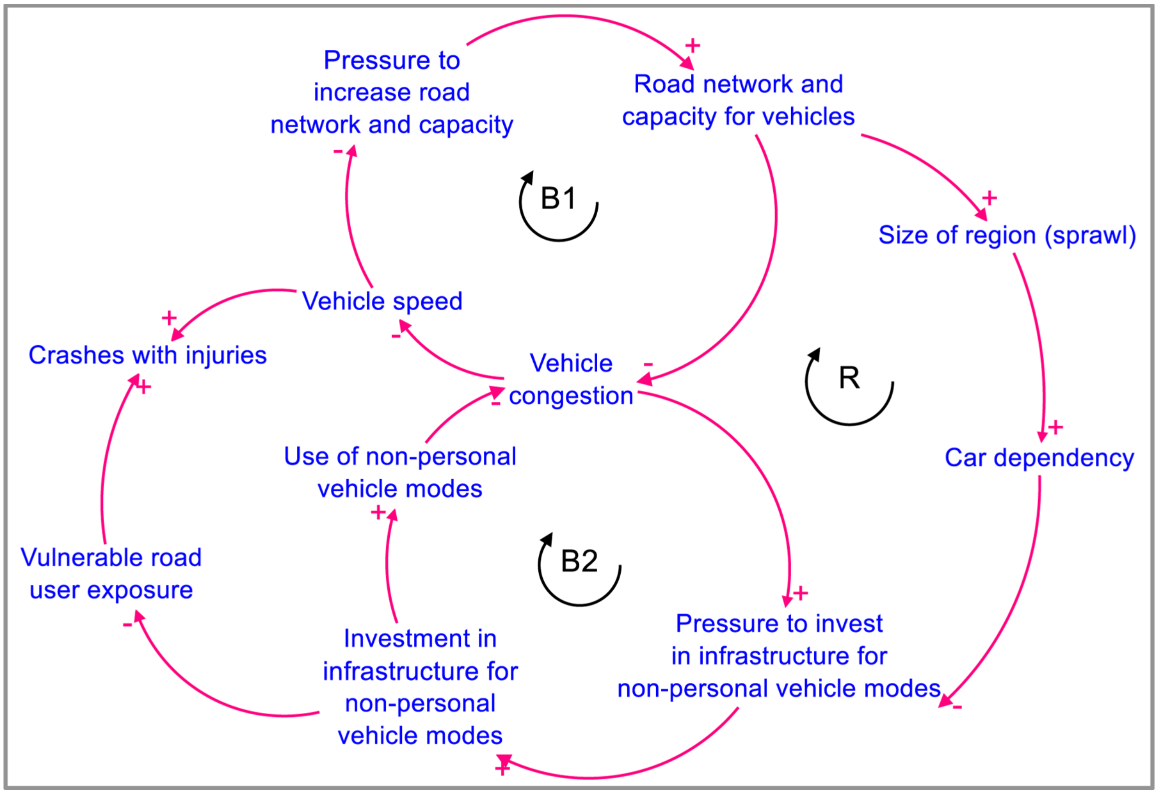

FIGURE 1.

Example causal loop diagram demonstrating interactions between vehicle speeds, sprawl, and crash risk

[Note: A causal arrow between two variables with a "+" sign indicates that as one variable increases (decreases), the other variable increases (decreases), as well, i.e., moves in the same direction. A causal arrow between two variables with a "−" sign indicates that as one variable increases (decreases), the other variable decreases (increases), i.e., moves in the opposite direction. "R" denotes a reinforcing feedback loop that amplifies change, and "B" denotes a balancing feedback loop that counteracts change.]

TABLE 1.

Examples of designing for human error

Approach aims to maximize…	Example
Functional harmony/ predictability/ recognizability	Gateway treatments (i.e., curb extensions used to mark the transition to a slower speed road); self-explaining roads (i.e., roads in which the function and design of the roadway cues the driver to adopt certain behaviors and speeds); curve delineation; standardized functional classes for roadways
Forgiveness	Vehicle roll cages (i.e., a protective frame to prevent injury in a rollover crash); cable median barriers (i.e., a forgiving barrier designed to prevent a vehicle from leaving the roadway or crossing into another direction of traffic); standard maximum speeds at intersections
Restrictiveness	Rumble strips (i.e., raised strips of pavement that alert a driver to the edge of the road or a slower zone by altering the noise of a vehicle's tires); vehicle lane-keeping assistance; interlock devices (i.e., a device designed to prevent vehicle operation when the driver is impaired)
Simplicity	Limit turning maneuvers, number of lanes, and/or direction of travel; simplify in-vehicle control panels
Understanding of human performance	Traffic signals timed for slower walking speeds; lights timed for slower reaction times; graduated driver licensing (i.e., a licensing system designed to provide new drivers with supervised driving time to develop their skills in a low risk environment)
Separation (in time or in space)	Separated/protected bike lanes; exclusive left phase; right turn on red restriction; exclusive traffic lanes; pedestrian refuge islands (i.e., a small section of pavement that provides a place for pedestrians to stop before completing a road crossing)
Speed control (to manage kinetic energy transfer)	Traffic calming measures (e.g., speed bumps); lower design speed; automated speed enforcement