Centre for Human Factors and Sociotechnical Systems

A Complex Systems Modelling Approach to Address Drug Driving-Related Road Trauma in Queensland

2025

Final Report

Acknowledgements

FUNDING

This project was funded by the Queensland Government Department of Transport and Main Roads.

PROJECT TEAM

The project was led by researchers from the Centre for Human Factors and Sociotechnical Systems:

- Professor Paul Salmon (Chief Investigator)
- Associate Professor Gemma Read
- Dr Scott McLean
- Dr Jolene Cox
- Professor Rod McClure.

STAKEHOLDERS

The project team would like to thank all the stakeholders who participated in our project.

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Executive Summary

Drug driving is a pressing issue in Australia and worldwide, yet there is limited understanding of the contributory factors of drug driving-related road trauma and the optimal ways to address drug driving. Building on recent calls for a systems thinking approach to address road safety challenges, this project involved the application of complex systems modelling methods to drug driving. Specifically, this project aimed to (i) identify the set of interrelated factors responsible for drug driving-related road trauma in Queensland and (ii) examine the likely impacts of potential interventions on the number of drug driving-related serious injury and fatal crashes in Queensland. Two methods were used to address these aims and they include a Causal Loop Diagram (CLD) and System Dynamics (SD) modelling.

PROJECT PHASES

The project involved the following four phases:

1. Initial data collection and ethics approval
2. Development of a qualitative CLD showing the factors that interact to create drug driving-related road trauma
3. Development of a quantitative SD model of drug driving-related road trauma to simulate the number of drug driving-related serious injury and fatal crashes over time
4. Identification of potential drug driving interventions and simulation of the likely impacts of these interventions on the number of drug driving-related serious injury and fatal crashes over a 30-year period.

MODEL DEVELOPMENT

Two stakeholder workshops were held during the project to develop the CLD and SD model.

The first stakeholder workshop involved 24 stakeholders from various disciplines and organisations (e.g., road/transport safety, policing, justice, public health). Stakeholders in this workshop contributed to the development of the CLD, by identifying the factors, and the interrelationships among the factors, they perceive to contribute to drug driving-related road trauma. A draft CLD was developed during the workshop and refined by the research team post-workshop. The final CLD informed the development of a draft SD model.

The second stakeholder workshop involved 9 stakeholders from various disciplines and organisations, similar to those in the first workshop. Stakeholders in this workshop contributed to the development of the SD model, by reviewing and providing feedback on the draft SD model developed by the research team (based on the final CLD). In this second workshop, stakeholders also discussed potential drug driving interventions to test and simulate in the SD model.

KEY FINDINGS

The CLD demonstrates that drug driving-related road trauma results from complex interrelationships among factors relating to societal drug use (recreational use, therapeutic/medicinal cannabis use, substance dependence), the road transport system and behaviour of its users, and road safety efforts. A key implication

from the CLD is that the issue of drug driving cannot be solely managed through road safety interventions such as enforcement, education, and awareness. Rather, a more holistic approach focusing on other influential aspects such as societal health, societal drug use, and availability of alternative forms of transport is recommended. This requires a whole of government approach to the problem of drug driving-related road trauma.

Based on the CLD, the SD model was developed and used to simulate the likely impacts of a series of potential interventions on drug driving-related serious injury and fatal crashes over a 30-year period. The outcome variable of the SD model was the annual number of drug driving-related serious injury and fatal crashes, with comparisons at the end of the 30-year simulation period with the number recorded in Queensland for the calendar year 2022. The following interventions, and combinations of interventions, were tested:

1. General roadside drug testing
2. Mandatory curriculum-based education program in schools (before licensure)
3. Broad-based education programs for drug driving
4. Roadside impairment testing technology
5. Increased penalties
6. Health-based interventions for individuals with illicit substance dependence
7. General intervention to address structural societal health concerns
8. Combination of Intervention 1 and Intervention 3
9. Combination of Intervention 3 and Intervention 6
10. Combination of Intervention 1 and Intervention 5
11. Combination of Intervention 1, Intervention 3, and Intervention 7.

Findings from the intervention testing indicate that most of the road safety interventions yield a modest estimated reduction (9.32–16.95%) in the number of drug driving-related serious injury and fatal crashes, with general roadside testing and roadside testing of impairment technology resulting in the greatest reduction. Increasing penalties did not result in any estimated change in the number of drug driving-related serious injury and fatal crashes. Across all the interventions tested, a combined, multi-domain intervention integrating efforts to address road safety (via enforcement and education) and societal health concerns (Intervention 11) resulted in the greatest estimated reduction (48.74%) in the number of drug driving-related serious injury and fatal crashes (48.74%). Findings from the intervention testing is consistent with our findings from the CLD, such that the findings highlight the need for and importance of a holistic, coordinated response from road safety authorities and other governments and organisations (e.g., the police, pharmaceutical companies, doctors and health professionals) to address drug misuse and dependence in the society and reduce the number of individuals driving under the influence of drugs.

CONCLUSION

This project adopted systems thinking approaches to understand and address drug driving-related road trauma in Queensland. The likely impacts of seven single interventions and four combined interventions on drug driving-related serious injury and fatal crashes were simulated over a 30-year time horizon via an SD model developed based on a CLD of drug driving-related road trauma in Queensland. Results from the simulation indicated that substantial reductions in crashes could be achieved through a combination of interventions that target road safety (i.e., general roadside drug testing and broad-based societal health education campaigns) and those that target societal health (i.e., general intervention that addresses structural societal health concerns). It is therefore concluded that a whole of government approach to the problem of drug driving is required, and that an initial important step is to establish an interdepartmental task force to explore the issue.

Section 1 | Background and Project Aims

Drug driving is one of the 'fatal five' behaviours known to be major behavioural contributory factors to road trauma. Drug driving is a longstanding issue that is complex to understand and difficult to prevent. The actual prevalence of drug driving is difficult to estimate (due to limitations with data collection), but estimates suggest that in Queensland, approximately 5–17% of drivers have driven under the influence of illicit drugs in the last 12 months (Libatique, 2024). Several interventions have been developed and implemented internationally to prevent drug driving, focusing mainly on driver education and enforcement (Razaghizad et al., 2021). However, there is little evidence for their effectiveness in reducing drug driving (Razaghizad et al., 2021). It is recognised that attempts to prevent road trauma should consider the entire road transport system, particularly the factors that influence road users' engagement in the fatal five behaviours (Salmon et al., 2012; Salmon & Lenné, 2015). A systems thinking perspective is therefore recommended when attempting to understand and prevent drug driving and the other fatal five behaviours (Salmon et al., 2019, 2020). Such an approach is yet to be applied to the problem of drug driving-related road trauma.

As part of ongoing efforts to understand and prevent drug driving in Queensland, the Queensland Government Department of Transport and Main Roads (TMR) funded the Centre for Human Factors and Sociotechnical Systems to examine the issue of drug driving and drug driving-related road trauma in Queensland. Specifically, the project aimed to apply complex systems modelling methods—Causal Loop Diagram (CLD) and System Dynamics (SD) Modelling—to:

(i) understand the dynamic, interrelated factors responsible for drug driving-related road trauma in Queensland
(ii) simulate the likely impacts of a range of interventions on drug driving-related serious injury and fatal crashes in Queensland.

This report describes the complex systems modelling research conducted and its findings.

PROJECT PHASES AND AIMS

There were four main phases in this project:

(i) Initial data collection and ethics approval

Phase 1 involved the collection and review of existing data to support Phases 2 and 3 of the project, and the submission of an ethics application to the University of the Sunshine Coast Human Ethics Committee for the research to be conducted in Phases 2–4 of the project.

(ii) Development of a drug driving-related road trauma CLD

Phase 2 involved the development of a conceptual CLD model describing the factors that interact to create drug driving-related road trauma in Queensland. The CLD model was developed in a group modelling workshop with road safety and public health stakeholders. The final CLD informed the development of the computational SD model (Phase 3).

(iii) Development of a drug driving-related road trauma SD model

Phase 3 involved the development of a quantitative, computational SD model of drug driving-related serious injury and fatal crashes in Queensland. This SD model illustrated the current dynamics surrounding drug driving-related serious injury and fatal crashes in Queensland and enabled the testing of different policy interventions for their likely impact on the number of serious injury and fatal crashes over time. The SD model was first drafted by the project team and then reviewed by road safety and public health stakeholders in a group modelling workshop.

(iv) Identification of drug driving interventions and simulation of likely impacts of the interventions on drug driving-related road trauma.

Phase 4 involved the identification of candidate drug driving interventions. This was achieved via a stakeholder workshop and further consultation with TMR representatives. The likely impacts of the identified set of interventions on the number of drug driving-related serious injury and fatal crashes (over a 30-year period) were tested in a series of simulations via the SD model.

Formal approval for the research was provided by the University of the Sunshine Coast Human Ethics Committee (A231976).

REPORT STRUCTURE

The structure of the report is as follows:

- Section 2 provides an overview of drug driving and systems thinking philosophy and methods (focusing on complex systems approaches)
- Section 3 presents an overview of Phase 2 of the project, including a description of the CLD model development and key findings
- Section 4 presents an overview of Phase 3 of the project, including a description of the SD model development and key findings
- Section 5 presents an overview of Phase 4 of the project, including a description of the interventions tested and the findings from the model simulations
- Section 6 summarises the findings from the project and outlines a set of recommendations for the prevention of drug driving-related road trauma in Queensland.

Section 2 | Introduction

Road trauma represents a major global health challenge. Road traffic injury is the leading cause of death for people aged 5–29 years and the 12th leading cause of death when all ages are considered (World Health Organization, 2023). The latest statistics from the WHO Global Status Report on Road Safety indicate that in 2021, road safety incidents resulted in the deaths of 1.19 million people and non-fatal injuries of 20–50 million people (WHO, 2023). In addition to this human cost, the economic cost of road trauma for societies worldwide is considerable, estimated to be around 1–3%, and in some cases, up to 6% of the Gross Domestic Product (GDP) (WHO, 2023). The cost of road crashes in Australia has been estimated at AUD$27 billion annually (~1.5% of Australia's GDP) (Lancsar et al., 2022). The significant scale of road trauma cannot be overstated.

A set of five driver behaviours (the 'fatal five') has been frequently cited as major contributors to road trauma. These behaviours include (i) speeding (Fondzenyuy et al., 2024), (ii) driving while fatigued (Dawson et al., 2021), (iii) driving while distracted (Overton et al., 2015), (iv) not wearing a seatbelt (Febres et al., 2020), and (v) driving under the influence of alcohol and drugs (Elvik, 2013; Love et al., 2023). Over the last several decades, many road safety interventions have been trialled and implemented to address these adverse behaviours and improve road safety (Fisa et al., 2022; Goel et al., 2024; Vecino-Ortiz et al., 2022). These interventions have focused on public awareness, education, enforcement, legislation, and engineering practices (Fisa et al., 2022). Despite the implementation of road safety interventions, there has been a plateau in improvements, with some increases in road trauma beginning to be observed. For example, between the years 2021 and 2022, the road fatality rate (per 100,000 population) increased from 4.3 to 4.5 in Australia, from 6.2 to 7.3 in New Zealand, and from 2.4 to 2.6 in the United Kingdom (Bureau of Infrastructure and Transport Research Economics, 2023). The limited progress in road safety improvement has been attributed to our current impoverished understanding of road safety, including road trauma causation (Salmon et al., 2012; Salmon & Lenné, 2015; Scott-Parker et al., 2015). Road safety research relating to addressing the fatal five behaviours has had a long-standing dominant focus on drivers, leading to the development and implementation of road safety interventions that target driver behaviours (Fisa et al., 2022). For example, interventions such as education, enforcement, or engineering (the "3 Es") are often relied upon (Fisa et al., 2022). Critically, this driver-centric focus neglects the broader road transport system (Salmon et al., 2012; Salmon & Lenné, 2015; Scott-Parker et al., 2015). In particular, factors beyond drivers that contribute to road safety (e.g., social and cultural norms or pressures, financial constraints around enforcement, job design) are often neglected in this reductionist road safety approach (Salmon et al., 2019). Further, this reductionist approach is at odds with alternative contemporary systems thinking-based models of accident causation, which argue for the need to consider how whole systems fail, rather than focusing on failures of components within the system (e.g., drivers) (Dekker, 2011).

The systems thinking philosophy applied to safety-critical systems has evolved through several accident causation models and analysis methods (e.g., Leveson, 2004; Rasmussen, 1997). Underpinning systems thinking-based models and methods is the notion that a system comprises multiple components (both human and technological), and it is from the interactions among these multiple components that safety and accidents emerge. This is particularly important because, in complex systems, the interactions among components are non-linear and difficult to predict, leading to potential unintentional consequences. For example, a decision to increase the cost of obtaining a driver's licence, with the intention of reducing the number of drivers and vehicles on the road, may inadvertently increase the number of unlicenced drivers and the engagement of unsafe driver behaviours. The adoption of systems thinking-based models and analysis methods has been advocated in road transport (Salmon et al., 2012; Salmon & Lenné, 2015; Scott-Parker et al., 2015).

A systems thinking-based method that has been applied to understand complex systems is *CLDs*. As mentioned, all systems comprise multiple components and the interactions among these multiple components influence behaviour. CLDs help us to better understand, conceptually, stakeholders' views on these interactions (feedback processes), the relationships that exist among them (feedback loops), and how they interact dynamically to influence behaviour (Sterman, 2000). Thus, CLDs are a valuable tool for capturing hypotheses about causal (cause-and-effect) dynamics, eliciting and capturing mental models, and communicating the feedback loops that may be responsible for a particular behaviour problem. Another systems thinking-based method is *SD modelling*. SD modelling enables the quantitative representation of complex feedback processes and dynamic mechanisms among components of the system under investigation (Sterman, 2000). Additionally, this method has also been used to simulate system behaviour over time and inform the likely impacts of system interventions. Thus, SD modelling serves as a valuable tool for creating a virtual "test bed" before real-world implementation, allowing researchers, policymakers, and other stakeholders to develop an understanding of a system and estimate the likely impacts of interventions. SD modelling is a useful decision support tool that can be used to anticipate policy implications and ultimately, inform policy decisions. These two systems thinking-based methods are complementary methods, such that CLDs are typically used to support the development of SD models (e.g., Naumann et al., 2022; Salmon et al., 2020); however, they can also be used independently (e.g., Allender et al., 2015; Littlejohns et al., 2018). Importantly, while these methods have been applied to understand and address complex issues pertaining to road and transport safety (e.g., Macmillan & Woodcock, 2017; Naumann et al., 2022; Salmon et al., 2020), they have not been applied to drug driving specifically.

RESEARCH CONTEXT: DRUG DRIVING IN QUEENSLAND

Drug driving is among the fatal five driving behaviours. Relative to the research on drink driving and the other fatal five driving behaviours, research on drug driving is less well-established. However, based on the current knowledge base, there is evidence suggesting adverse impacts of drug consumption on driving performance (Dini et al., 2019; Simmons et al., 2022). For example, amphetamine and benzodiazepine consumption increases unsafe driving (e.g., speeding, weaving from side to side when driving, improper lane changing) (Bosanquet et al., 2013; Dubois et al., 2008). There is also evidence suggesting an increased risk of crashes due to consumption (Elvik, 2013). For example, cannabis consumption has been associated with a 1.65-fold increased risk of a fatal crash (Martin et al., 2017) and benzodiazepine consumption has been associated with a 1.42-fold increased risk of a crash (Orriols et al., 2016).

Drug driving is prevalent in Australia. Recent statistics from the 2024 National Illicit Drug Reporting System (Sutherland et al., 2024) indicate that among participants who drove in the last six months, a staggering 77% reported driving within three hours of consuming an illicit or non-prescribed drug. Among these participants, crystal methamphetamine (59%) was the most common drug consumed before driving, followed by heroin (40%) and cannabis (37%). Drug driving is a pressing issue in Queensland, with further jurisdictional analyses conducted as part of the Illicit Drug Reporting System indicating that 73% of participants reported drug driving in the last six months (based on 2023 data) (Juckel et al., 2023). Additional road safety statistics from

Queensland emphasise the extent of this issue. Statistics from the Queensland Department of Transport and Main Roads indicate that in the calendar of 2022, there were 56 fatal and 180 serious injury (hospitalised) crashes attributed to drug driving. And statistics from the Queensland coroner's data indicate that drugs were present in 24.8% of fatal crashes (based on 2015 data) (Davey et al., 2020). The state of road safety will likely worsen over time if effective interventions are not implemented to reduce drug driving on Queensland roads.

The primary interventions for drug driving focus on preventative activities and these activities can be categorised into deterrence or education (Razaghizad et al., 2021). Deterrence activities mainly involve the implementation of roadside drug testing, which tests for traces of certain drugs in bodily fluid (often saliva), and the implementation of penalties (fines, suspension of driver licence). The intent behind these interventions is to prevent drug driving via legal punishment. In Queensland (and the rest of Australia), drug driving laws adopt a "zero tolerance" approach, meaning that any trace of relevant drugs in one's system is deemed illegal while driving. Relevant drugs include methylamphetamine, MDMA (active ingredient in ecstasy), THC (active ingredient in cannabis), and cocaine. The criminal offence is associated with strict penalties, for example, an immediate 24-hour suspension of driver licence (Queensland Government, 2024). Roadside drug testing is predominantly targeted in Queensland. Educational activities involve a range of targeted educational programs designed to prevent drivers from drug driving, or mass media campaigns designed to increase awareness of the adverse consequences of drug driving. In addition to these primary interventions, other health-based rehabilitative activities (e.g., Osilla et al., 2019) are beginning to be explored as potential interventions for drug driving. It should be noted that while these drug driving interventions are being developed and implemented, evaluation efforts have been poor. There is limited evidence on the impacts of these interventions on reducing drug driving and drug driving-related crashes. Additionally, these drug driving interventions mainly target the driver, with no consideration of the broader systemic factors that could influence drug driving (e.g., societal health, policy, and economic influences). This project addressed the gaps in the current knowledge base by

(i) identifying the set of interrelated factors responsible for drug driving-related road trauma (using CLD), and
(ii) examining the likely impacts of potential road safety interventions on the number of serious injury and fatal crashes (using SD modelling).

GENERAL METHODS

There were three main phases involved in the complex systems modelling approach taken for this project:

(i) the development of a CLD
(ii) the development of an SD model, and
(iii) policy design and simulation.

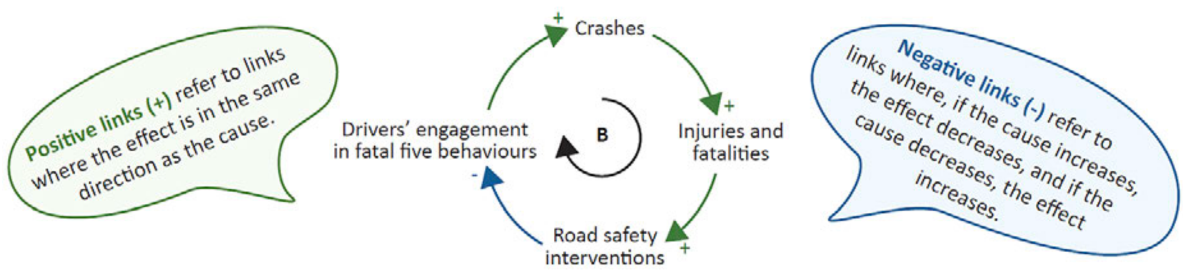
Further methodological details of the three phases are described in the following sections.

Section 3 | Phase 2: Development of a drug driving-related road trauma CLD

A CLD was developed to represent stakeholders' views of the interrelated factors responsible for drug driving-related road trauma in Queensland. All systems comprise interacting networks of positive and negative feedback loops that influence behaviour (Sterman, 2000). CLD is a method that is used to elicit and represent stakeholder views on what these positive and negative feedback loops comprise, what relationships exist between them, and how they interact dynamically to influence behaviour. In a CLD, factors are connected using causal arrows with polarity or links to diagrammatically illustrate hypothetical or empirically-driven causal relationships. Causal arrows with a positive polarity (a "+" sign) indicate that a change in the source factor causes a change in the destination factor in the same direction. In other words, as one factor increases, the other factor also increases, or as one factor decreases, the other factor also decreases. Causal arrows with a negative polarity ("-" sign) indicate that a change in the source factor causes a change in the destination factor in a different direction. In other words, as one factor increases, the other factor decreases, or as one factor decreases, the other factor increases. If causal connections form a closed chain of events over time, they create reinforcing or balancing loops, depending on the combined polarities of the arrows in the loop. An example of a balancing loop is presented in Figure 1 (from Salmon et al., 2020). According to the loop, as the number of drug driving-related crashes increases, the number of crash-related injuries and fatalities increases, which in turn, leads to the implementation of more road safety interventions. As the interventions take effect, the number of drivers driving under the influence of drugs decreases. This reduction in drivers driving under the influence of drugs leads to a decrease in the number of drug driving-related crashes, injuries, and fatalities.

A group modelling process (Bérard, 2010; Sterman, 2000) was used to develop a CLD of drug driving-related road trauma. The research team conducted a stakeholder workshop as part of this process.

FIGURE 1. A ROAD SAFETY EXAMPLE OF A BALANCING LOOP



WORKSHOP PARTICIPANTS

Relevant stakeholders were identified in consultation with TMR representatives. The stakeholders were invited to participate in a 1-day in-person workshop in Brisbane, Queensland. A total of 24 stakeholders (10 male, 14 female) from across various disciplines and organisations participated in this workshop, bringing expertise in road and transport safety (*n* = 9), policing (*n* = 6), justice (*n* = 4), and public health, including drug and alcohol services and ambulance services (*n* = 4). The mean age of participants was 43.54 years (*SD* = 13.26, *range* = 22–69). Participants' self-ratings of their knowledge and skills relevant to this study can be found in Table 1. It should be noted that although participants were asked to self-rate their knowledge and skills relevant to this study, they were not required to be highly knowledgeable or skilled in all the areas assessed, especially in human factors and systems thinking methods (including causal loop diagrams and system dynamics modelling).

TABLE 1. CAUSAL LOOP DIAGRAM WORKSHOP: PARTICIPANTS' KNOWLEDGE AND SKILLS RELEVANT TO THIS PROJECT

Expertise	Very good n (%)	Good n (%)	Fair n (%)	Poor n (%)	Very poor n (%)
Road safety	7 (29.17)	13 (54.17)	3 (12.50)	1 (4.17)	0 (0.00)
Road crashes (including causes of road crashes)	5 (20.83)	9 (37.50)	8 (33.33)	2 (8.33)	0 (0.00)
Drug driving (illicit drugs)	6 (25.00)	8 (33.33)	6 (25.00)	4 (16.67)	0 (0.00)
Drug driving (licit drugs)	4 (16.67)	4 (16.67)	13 (54.17)	3 (12.50)	0 (0.00)
Drug driving prevention	4 (16.67)	6 (25.00)	11 (45.83)	3 (12.50)	0 (0.00)
Drug driving enforcement	6 (25.00)	6 (25.00)	9 (37.50)	3 (12.50)	0 (0.00)
Drug supply/misuse law enforcement	2 (8.33)	8 (33.33)	13 (54.17)	1 (4.17)	0 (0.00)
Drug rehabilitation	3 (12.50)	7 (29.17)	10 (41.67)	4 (16.67)	0 (0.00)
Public health	5 (20.83)	7 (29.17)	10 (41.67)	2 (8.33)	0 (0.00)
Human factors and systems thinking methods	1 (4.17)	10 (41.67)	8 (33.33)	5 (20.83)	0 (0.00)
Causal loop diagrams	1 (4.17)	3 (12.50)	10 (41.67)	7 (29.17)	3 (12.50)
System dynamics	0 (0.00)	5 (20.83)	12 (50.00)	6 (25.00)	1 (4.17)

ANALYSIS BOUNDARY

The boundary for the CLD development and analysis was established as drug driving-related road trauma in Queensland.

PROCEDURE

In the stakeholder workshop, the research team provided a background on CLDs before stakeholders engaged in the workshop activities. Stakeholders were first asked to identify factors they believed to be responsible for drug driving-related road trauma in Queensland. To do this, stakeholders worked in small groups to identify the factors. The factors identified by all the groups were collated into an online visual board (Google Jamboard) and categorised into broad themes (e.g., factors relating to enforcement, societal health, alternative transport availability). The factors were then entered into the software, Vensim, which enabled the drawing of the CLD. Stakeholders were then asked to identify the relationships among the factors, resulting in a first draft of the

CLD. The draft CLD was refined by the research team post-workshop through an iterative process. The final CLD was drawn using the online visualisation software tool, Kumu (https://kumu.io).

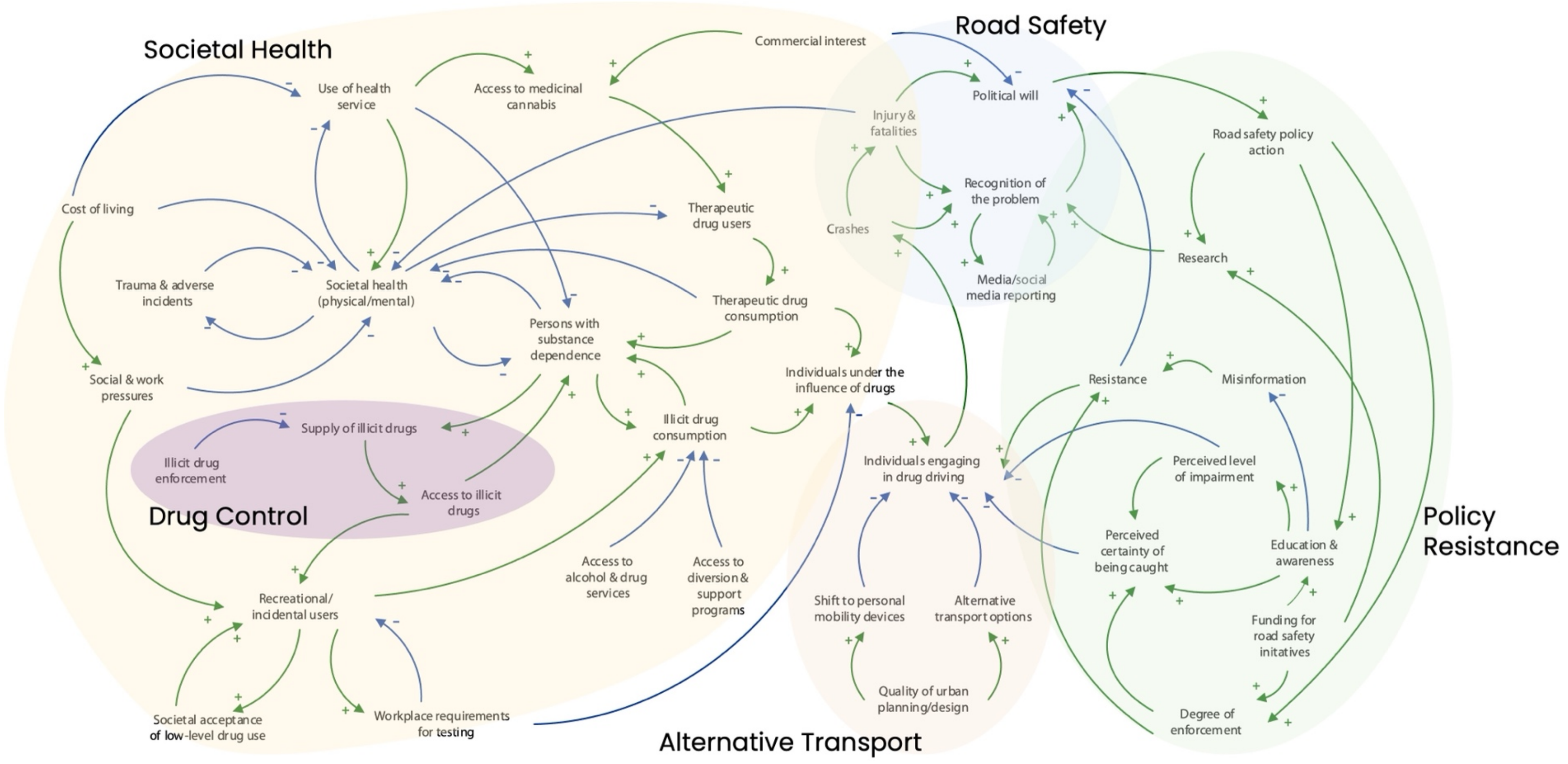
KEY FINDINGS

The final CLD is presented in Figure 2. Definitions of the factors in the CLD can be found in Table A of the Appendix.

Stakeholders identified factors, and interrelationships between factors, from across five distinct groups, that they believe create drug driving-related road trauma: (i) societal health, (ii) drug control, (iii) road safety, (iv) alternative transport, and (v) policy resistance. The CLD describes three drug user populations that contribute to the number of individuals engaging in drug driving on Queensland roads. The three drug user populations include recreational or incidental users, therapeutic drug users (i.e., medicinal cannabis users), and persons with illicit substance dependence. Factors relating to societal health were key influencers in the use of drugs; for example, a history or presence of trauma and adverse incidents, increased cost-of-living pressures, increased social and work pressures, and a lack of access to health services. Factors relating to drug control (e.g., access to drugs and supply of drugs) were also influencers in the use of drugs. As societal health and drug control decrease, the three drug user population grows, resulting in more individuals engaging in drug driving. This, in turn, increases the number of drug driving-related crashes and subsequently, the number of injuries and fatalities. The increases in drug driving-related road trauma exacerbate the gap between the actual state and the goal state of road safety, heightening the recognition that drug driving is a problem. This heightened recognition increases the political will to address the problem. Road safety policy action tends to escalate, resulting in more research and greater efforts to intervene and reduce drug driving-related road trauma. However, the increase in policy action may also lead to greater policy resistance, reducing the effectiveness of the policy action taken.

A notably observation from the CLD is that drug driving is not a road safety issue per se, and thus, the issue of drug driving cannot be solely managed through road safety interventions such as enforcement, education, and awareness. Given the multi-factorial nature of drug driving, a more holistic approach focusing on other influential aspects such as societal health, societal drug use, and alternative forms of transport is recommended. This requires a whole-of-government approach to addressing the problem of drug driving-related road trauma.

FIGURE 2. CAUSAL LOOP DIAGRAM OF DRUG DRIVING-RELATED ROAD TRAUMA



Note. The arrows represent the causal relationships among the factors. Causal arrows with a positive polarity (a "+" sign, green-coloured arrows) indicate a change in the same direction. Causal arrows with a negative polarity (a "-" sign, blue-coloured arrows) indicate a change in a different direction.

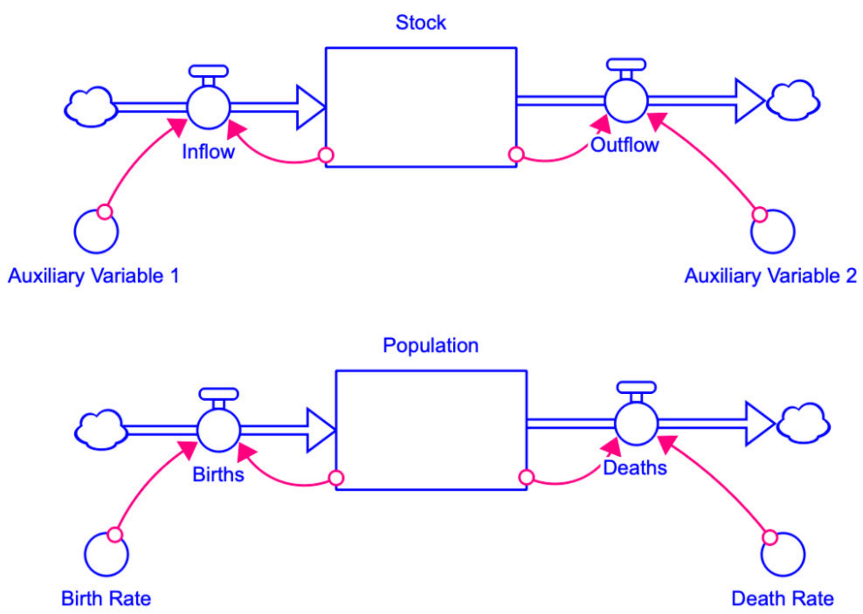
Section 4 | Phase 3: Development of a drug driving-related road trauma SD model

An SD model was developed by converting the CLD into a formal quantitative model, representing the overall system architecture (model that defines the structure and behaviour of a system) for drug driving-related road trauma in Queensland.

In SD models, stocks and flows are the building blocks. Stocks are variables that accumulate the effects of other variables in the system and they are measured at one specific time point. An example of a stock is the total population. Flows are the rates at which stocks change at any given time point. They either flow into a stock ("inflow", causing a stock to increase) or flow out of a stock ("outflow", causing a stock to decrease). An example of an inflow is the population growth rate, and an example of an outflow is the population death rate. System dynamics models also comprise auxiliary (information) variables. Auxiliary variables are independent of the values of stocks and flows. Auxiliary variables facilitate the functional dependencies between stocks and flows. An example of stocks, flows, and auxiliary variables is presented in Figure 3. When developing a system dynamics model, the stocks and flows are represented before the auxiliary variables. The model is then expressed using differential equations. It is important to note that every variable and equation must represent an aspect of the system architecture.

A draft SD model of drug driving-related road trauma in Queensland was drafted by the research team, and then reviewed by stakeholders in a workshop.

FIGURE 3. AN EXAMPLE OF STOCKS, FLOWS, AND AUXILIARY VARIABLES



WORKSHOP PARTICIPANTS

Participants from the first workshop (workshop on the development of a causal loop diagram), and other relevant stakeholders, were invited to participate in an online workshop on Microsoft Teams, A total of nine stakeholders (4 male, 5 female) from across various disciplines and organisations participated in this workshop, bringing expertise in road and transport safety (n = 5), policing (n = 1), justice (n = 2), and public health (n = 1). The mean age of participants is 42.89 (SD = 8.05, *range* = 32–57). Participants' self-rating of their knowledge and skills relevant to this study can be found in Table 2.

TABLE 2. SYSTEM DYNAMICS MODELLING WORKSHOP: PARTICIPANTS' KNOWLEDGE AND SKILLS RELEVANT TO THIS PROJECT

Expertise	Very good n (%)	Good n (%)	Fair n (%)	Poor n (%)	Very poor n (%)
Road safety	2 (22.22)	6 (66.67)	1 (11.11)	0 (0.00)	0 (0.00)
Road crashes (including causes of road crashes)	2 (22.22)	3 (33.33)	4 (44.44)	0 (0.00)	0 (0.00)
Drug driving (illicit drugs)	3 (33.33)	3 (33.33)	2 (22.22)	1 (11.11)	0 (0.00)
Drug driving (licit drugs)	1 (11.11)	2 (22.22)	6 (66.67)	0 (0.00)	0 (0.00)
Drug driving prevention	2 (22.22)	1 (11.11)	6 (66.67)	0 (0.00)	0 (0.00)
Drug driving enforcement	2 (22.22)	2 (22.22)	5 (55.56)	0 (0.00)	0 (0.00)
Drug supply/misuse law enforcement	1 (11.11)	2 (22.22)	5 (55.56)	1 (1.11)	0 (0.00)
Drug rehabilitation	1 (11.11)	2 (22.22)	3 (33.33)	3 (3.33)	0 (0.00)
Public health	2 (22.22)	2 (22.22)	4 (44.44)	1 (11.11)	0 (0.00)
Human factors and systems thinking methods	0 (0.00)	5 (55.56)	3 (33.33)	1 (11.11)	0 (0.00)
Causal loop diagrams	1 (11.11)	2 (22.22)	3 (33.33)	3 (33.33)	0 (0.00)
System dynamics	0 (0.00)	4 (44.44)	3 (33.33)	2 (22.22)	0 (0.00)

ANALYSIS BOUNDARY

The boundary for the SD model development was established as drug driving-related road trauma in Queensland. More specifically, the crashes resulting in serious injuries and fatalities caused by drivers driving under the influence of drugs occurring within the Queensland road transport system.

PROCEDURE

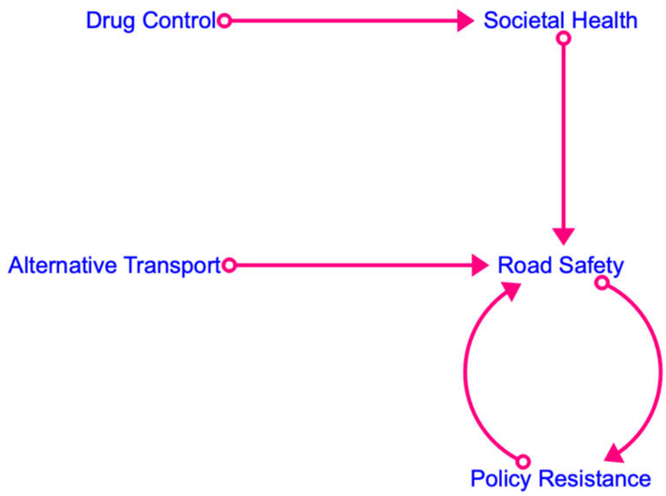
The research team drafted the structure of the SD model, using the CLD as a basis. The draft structure was reviewed by stakeholders in a stakeholder workshop. In the stakeholder workshop, the research provided a summary of the first workshop, including the final CLD and a background on SD modelling. The stakeholders then engaged in the main activity, which was reviewing and providing feedback on the model structure. The SD model was further refined by the research team post-workshop through an iterative process.

Once the SD model structure was completed, the research team obtained empirical data from various sources (e.g., government agencies, published literature). As is the case for many SD models, it was often impractical and impossible to obtain the necessary data for all of the variables because of limitations in the availability of the data. Therefore, where empirical data were unavailable, estimations were made based on the other available proxy data. The model was then validated through an iterative process to ensure that it represented the behaviour of the real system. The SD model was developed using Stella Architect Version 3.5.1 (https://www.iseesystems.com/). The model variables, data, and equations can be found in Table B of the Appendix.

KEY FINDINGS

An overview of the system dynamics model is presented in Figure 4. This illustrates the causal connections among the five model sectors. The five model sectors represent the five distinct groups of interrelated factors identified in the CLD. Detailed structure of each model sector is presented in Figures 5–9.

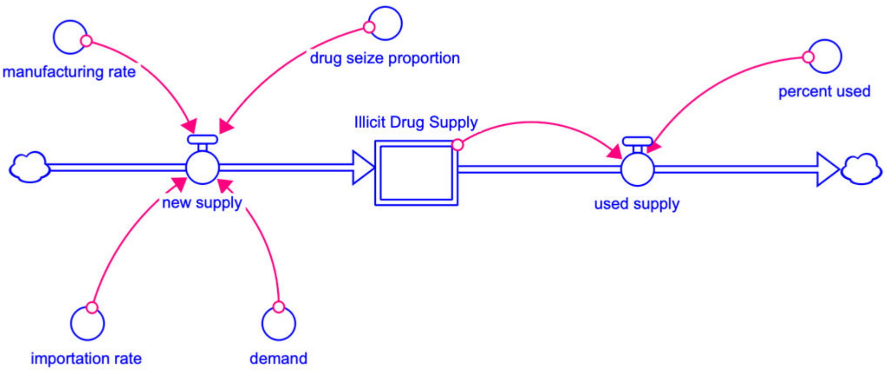
FIGURE 4. AN OVERVIEW OF THE SD MODEL OF DRUG DRIVING-RELATED ROAD TRAUMA



Note. The arrows indicate the causal connections among the model sectors.

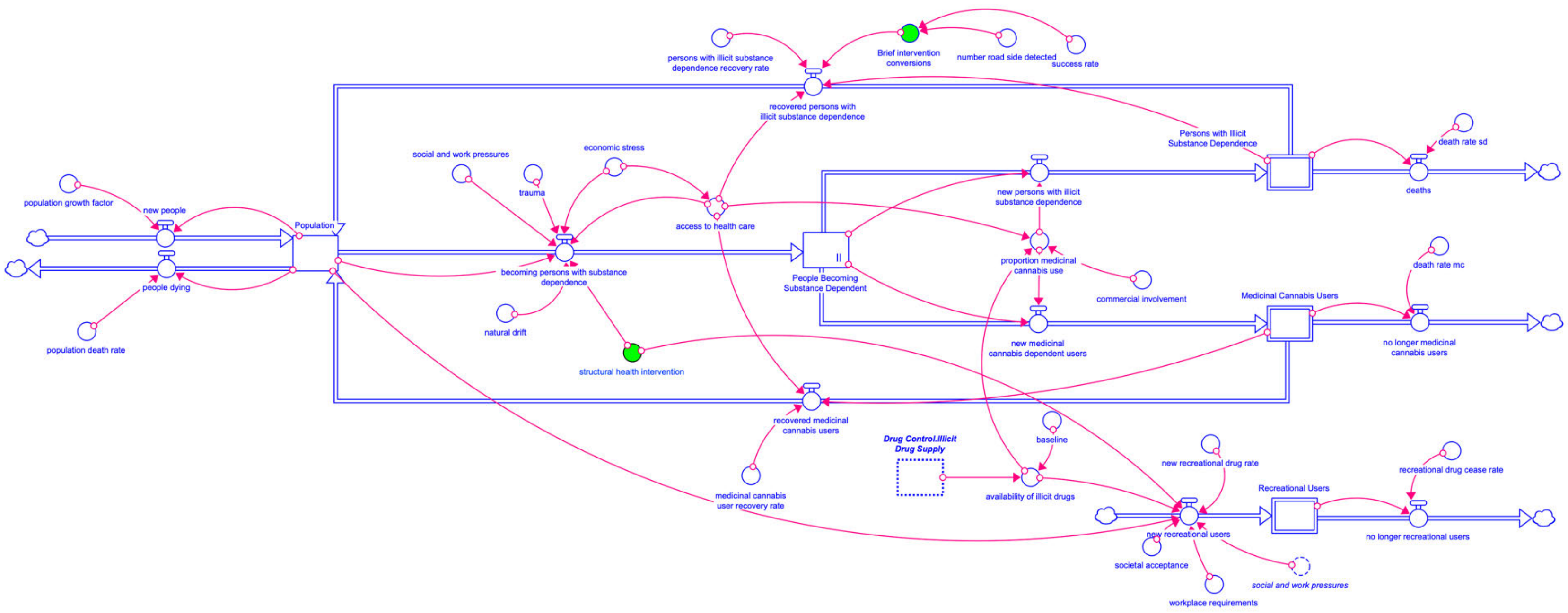
The Drug Control model sector (Figure 5) describes the illicit drug supply. Illicit drug supply increases with new supply, which is influenced by drug manufacturing and importation rates, the demand for drugs, and the proportion of drugs seized. Illicit drug supply decreases with the supply being used.

FIGURE 5. DRUG CONTROL MODEL SECTOR



The Societal Health model sector (Figure 6 on the next page) describes the three main drug user populations within the Queensland population (15 years of age and older). The three drug user populations include persons with illicit substance dependence, medicinal cannabis users, and recreational users. Substance dependence (either dependence on illicit substances or medicinal cannabis) is influenced by social and work pressures, trauma, economic stress, and access to health care. Recreational drug use is influenced by societal acceptance of drugs, social and work pressures, availability of illicit drugs, and workplace requirements to not be under the influence of drugs.

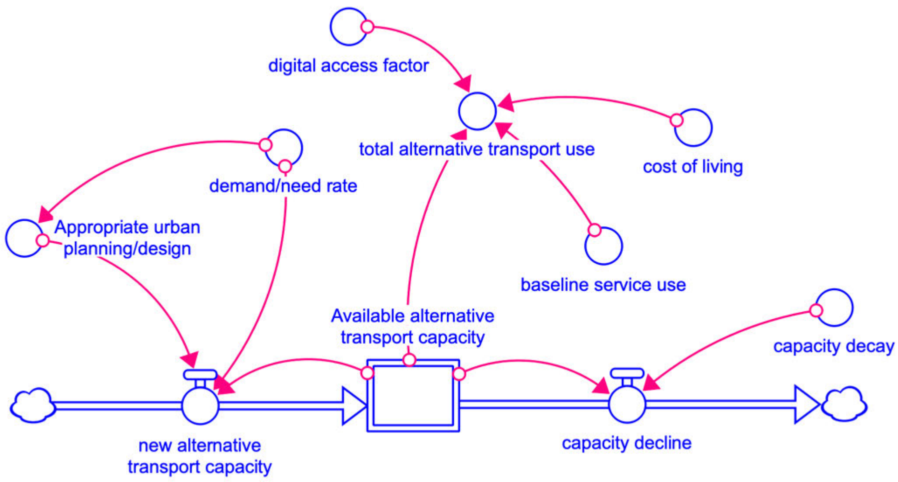
FIGURE 6. SOCIETAL HEALTH MODEL SECTOR



Note. The variables in green relate to the drug driving interventions described in Section 5 of the Report.

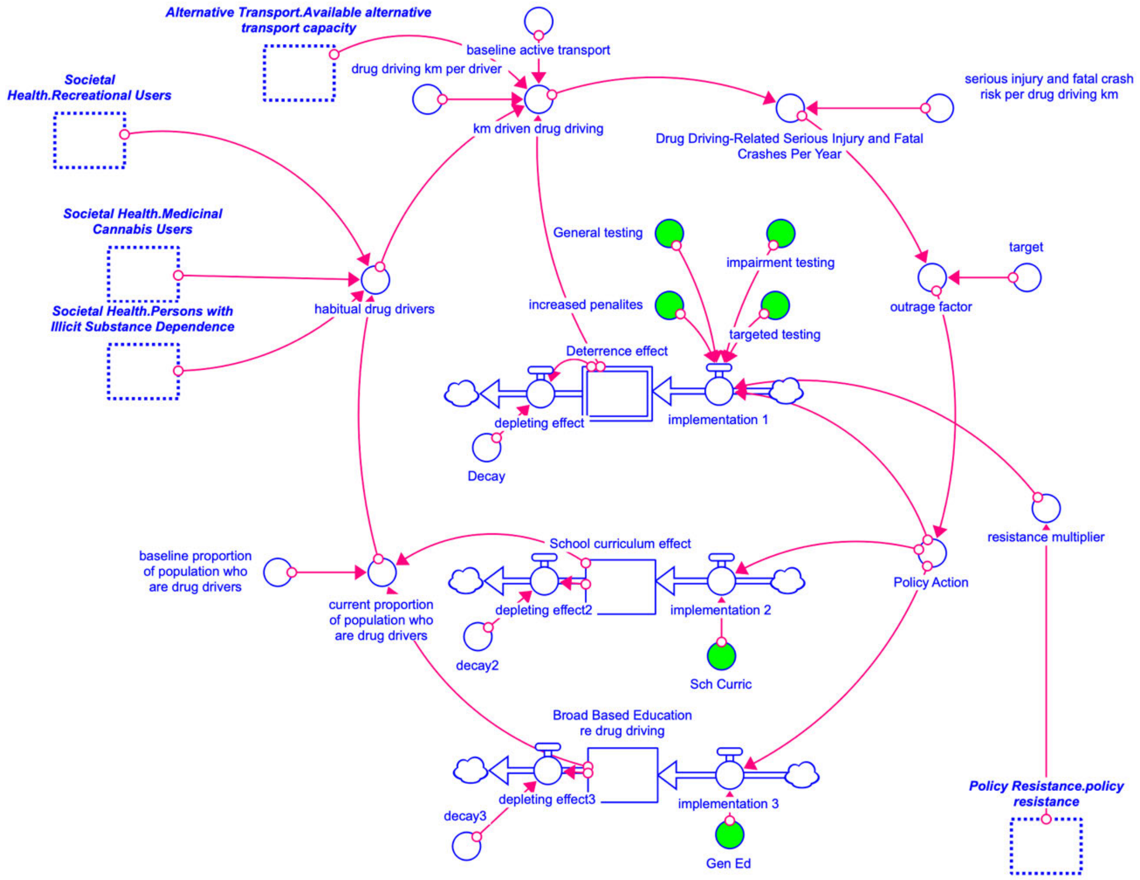
The Alternative Transport model sector (Figure 7) describes the capacity of available alternative transport. Capacity increases with appropriate urban planning or design and demand for alternative transport. Capacity decreases with a capacity decay. Critically, the total alternative transport use is influenced by the available alternative transport capacity, cost of living, and digital access (e.g., bus scheduling apps).

FIGURE 7. ALTERNATIVE TRANSPORT MODEL SECTOR



The Road Safety model sector (Figure 8) describes the number of drug drivers on Queensland roads, the kilometres driven under the influence of drugs, and the number of drug driving-related serious injury and fatal crashes each year. The model also describes how the number of drug driving-related serious injury and fatal crashes drives policy action, leading to the implementation of different interventions (discussed in Section 5 of this Report). This, in turn, influences the number of drug drivers or the kilometres driven under the influence of drugs.

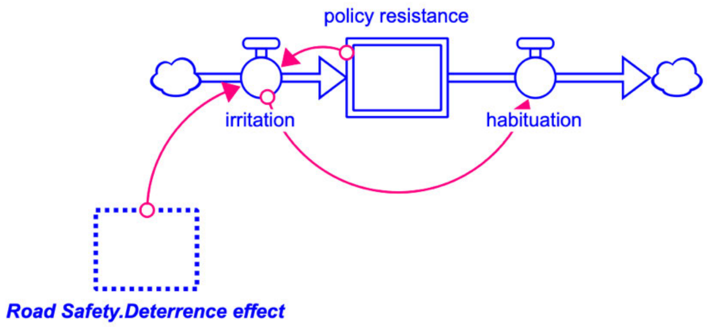
FIGURE 8. ALTERNATIVE TRANSPORT MODEL SECTOR



Note. The variables in green relate to the drug driving interventions described in Section 5 of the Report.

The Policy Resistance model sector (Figure 9) describes how the implementation of drug driving interventions (e.g., deterrence activities) creates a public compliance burden, which leads to pushback against road safety policies, influencing policy action.

FIGURE 9. POLICY RESISTANCE MODEL SECTOR



Section 5 | Phase 4: Simulation of likely impacts of drug driving interventions

The SD model was designed to allow for the testing of different interventions intended to reduce drug driving-related road trauma in Queensland. The identification of drug driving interventions for testing via the SD model occurred during the second workshop (workshop on the development of the system dynamics model).

WORKSHOP PARTICIPANTS

Information about the workshop participants can be found in Section 4 of the Report.

PROCEDURE

After participants reviewed and provided feedback on the structure of the SD model during the second workshop, participants discussed potential drug driving interventions that could be tested in the SD model. Participants discussed in small groups, with each group focusing on interventions relevant to one of the model sectors in the SD model. The drug driving interventions identified by participants were collated by the research team. The research team discussed the list of proposed interventions with TMR representatives, resulting in the prioritisation of seven interventions, and combinations of these interventions, for test using the SD model. Descriptions of the drug driving interventions tested in the model can be found in Table 3.

The interventions tested were as:

12. General roadside drug testing
13. Mandatory curriculum-based education program in schools (before licensure)
14. Broad-based education programs for drug driving
15. Roadside impairment testing technology
16. Increased penalties
17. Health-based interventions for individuals with illicit substance dependence
18. General intervention to address structural societal health concerns
19. Combination of Intervention 1 and Intervention 3
20. Combination of Intervention 3 and Intervention 6
21. Combination of Intervention 1 and Intervention 5
22. Combination of Intervention 1, Intervention 3, and Intervention 7.

INTERVENTION SIMULATION CONDITIONS

The research team simulated the likely impacts of these interventions on the number of drug driving-related serious injury and fatal crashes per year, over a 30-year period.

The effect sizes for the interventions tested were estimated based on a literature review. Due to the limited empirical research on the impacts of these interventions on drug driving-related road trauma, the research team gathered evidence from other proxy literature (e.g., drink driving interventions to address drink driving-related road trauma), discussed the evidence, and made a consensus decision on the estimated effect sizes for input into the system dynamics model (see Table B of the Appendix). As an example, it was estimated that the implementation of broad-based education programs for drug driving would result in a 15% reduction in drug driving-related serious injury and fatal crashes (the effect size entered for this intervention variable was 1.15). This estimation was based on the review of the effectiveness of mass media campaigns on drink driving-related crashes (Yadav & Kobayashi, 2015).

TABLE 3. INTERVENTIONS TESTED IN THE SYSTEM DYNAMICS MODEL OF DRUG DRIVING-RELATED ROAD TRAUMA

Intervention	Description	Intended direct effect(s)
1. General roadside drug testing	High visibility, high volume roadside drug testing, with the main purpose of deterring the general driving population from drug driving	Reduces the number of kilometres driven under the influence of drugs
2. Mandatory curriculum-based education program in schools (before licensure)	Curriculum-embedded education program aimed at increasing awareness of the consequences of drug driving, for school-aged individuals before they obtain their driver licence	Reduces the proportion of population who are drug drivers
3. Broad-based education campaigns for drug driving	Media and social media campaigns to increase awareness of the consequences of drug driving, for the broader public	Reduces the proportion of population who are drug drivers
4. Roadside impairment testing technology	Technology that can be implemented on the road to identify impairment from drug use (e.g., psychomotor testing)	Reduces the number of kilometres driven under the influence of drugs
5. Increased penalties	Increase the amount and severity of penalties if caught drug driving	Reduces the number of kilometres driven under the influence of drugs
6. Health-based interventions for individuals with illicit substance dependence	Health-based interventions (e.g., cognitive behavioural therapy, motivational interviewing) aimed at recovery from substance dependence in people with illicit substance dependence	Increases the number of individuals who have recovered from illicit substance dependence
7. General intervention to address structural societal health concerns	General intervention aimed at addressing the factors contributing to drug consumption in society (e.g., economic stress, trauma, social and work pressures)	Reduces the number of individuals with substance dependence (illicit or medicinal cannabis) and individuals who take drugs recreationally

KEY FINDINGS

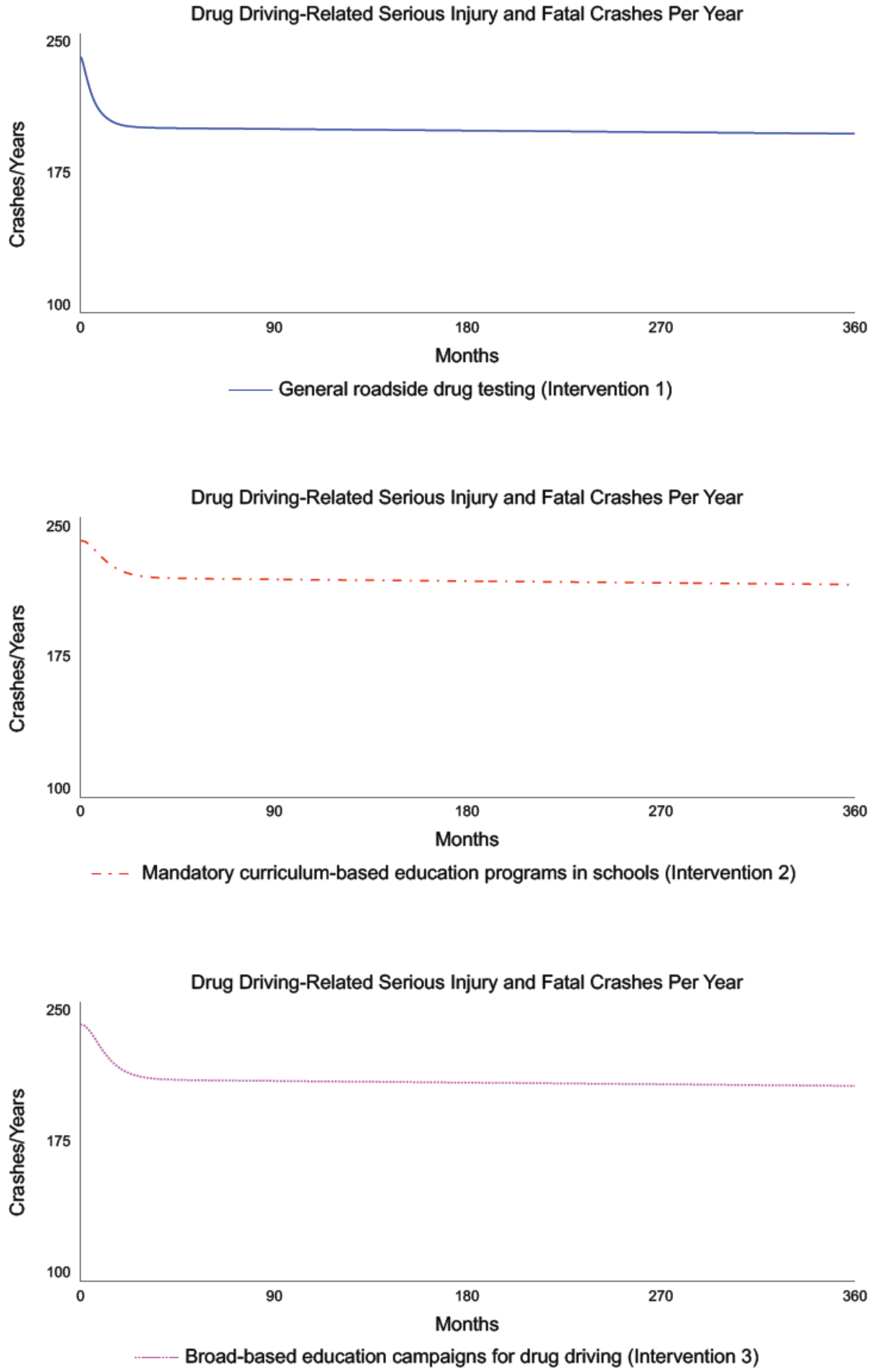
Graphs illustrating the likely impacts of the drug driving-related interventions tested can be found in Figures 10 and 11 (single interventions) and Figure 12 (combined interventions). A summary of the outcomes of the interventions tested can be found in Table 4.

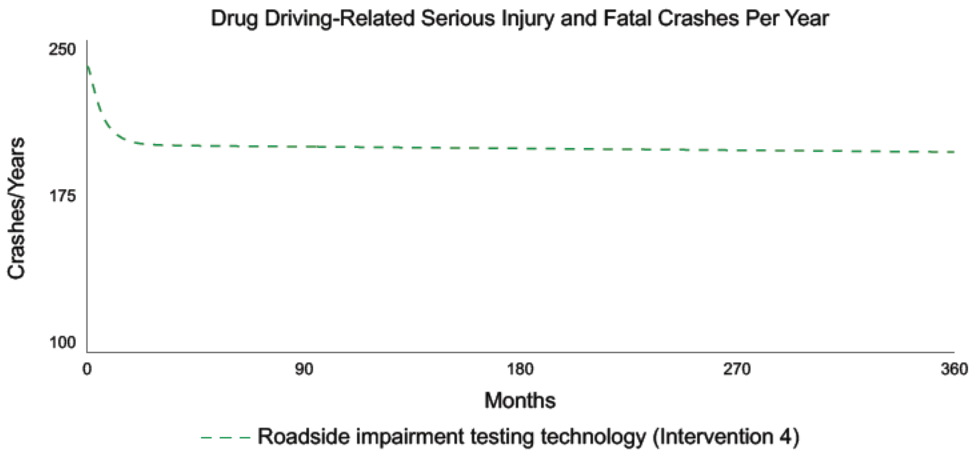
The first five interventions involve road safety efforts and therefore, targeted the road safety model sector. The implementation of general roadside drug testing is projected to decrease the number of drug driving-related serious injuries and fatal crashes (hereafter referred to as "crashes") by 16.95% (from 236 crashes in the calendar year 2022 [baseline] to 196 crashes in 2052). Mandatory curriculum-based education programs in schools (before licensure) are projected to have a smaller effect, with a decrease in crashes of 9.32% (from baseline to 214 crashes). The delivery of broad-based societal health education campaigns for drug driving is projected to decrease the number of crashes by 13.13% (from baseline to 205 crashes). The implementation of roadside impairment testing technology is projected to have the same effect as the implementation of general roadside drug testing, with a 16.95% decrease in the number of crashes (from baseline to 196 crashes). Increasing penalties has no effect on the number of crashes. The implementation of general roadside drug testing and roadside impairment testing technology for drug driving appears to have bigger independent effects when compared to other road safety interventions.

Two interventions targeted the societal health model sector. The health-based interventions for individuals with illicit substance dependence is projected to have a small marginal effect on the number of crashes (from baseline to 237). Assuming the same amount of effort for road safety interventions was applied to address structural societal issues, a general societal health intervention is projected to decrease the number of crashes by 29.24% (from baseline to 167 crashes).

Combinations of interventions were also tested. The combined intervention of general roadside drug testing and broad-based societal health education campaigns for drug driving is projected to decrease the number of crashes by 27.54% (from baseline to 171 crashes). The combined intervention of broad-based societal health education campaigns for drug driving and health-based interventions for individuals with illicit substance dependence is projected to decrease the number of crashes by 12.71% (from baseline to 206 crashes). The combined intervention of general roadside drug testing and increased penalties is projected to decrease the number of crashes by 16.95% (from baseline to 196 crashes), which is identical to the effect observed for general roadside drug testing alone (no effect observed for increased penalties). Finally, the combined intervention of general roadside drug testing, broad-based societal health education campaigns, and a general societal health intervention is projected to decrease the number of crashes by 48.74% (from baseline to 121 crashes).

FIGURE 10. SINGLE INTERVENTIONS (ROAD SAFETY)




Drug Driving-Related Serious Injury and Fatal Crashes Per Year
250
175
100
Crashes/Years
0
90
180
270
360
Months
Roadside impairment testing technology (Intervention 4)

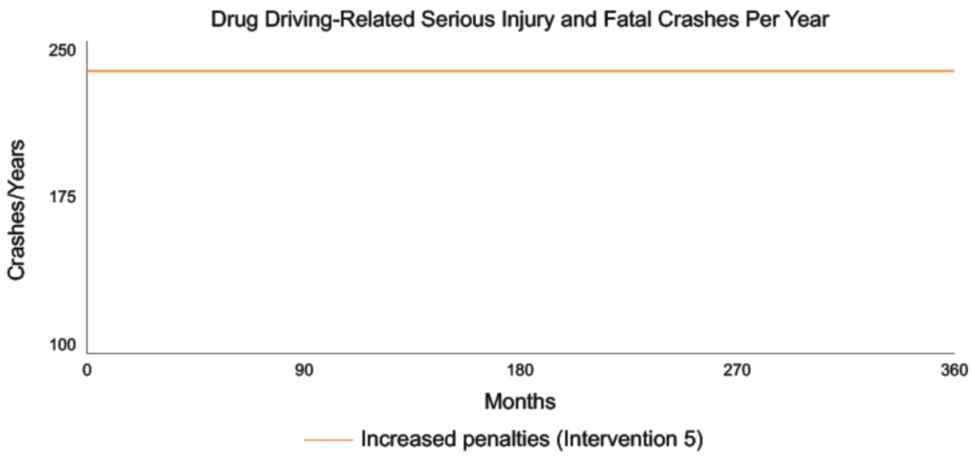
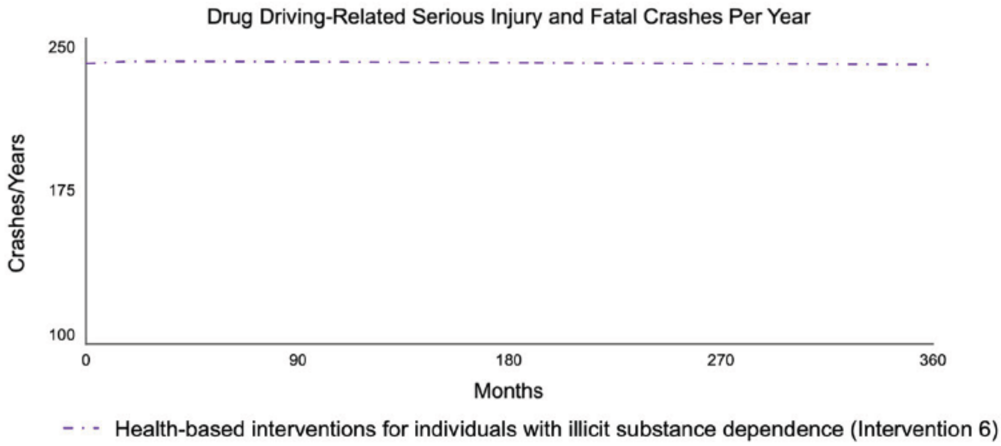

Drug Driving-Related Serious Injury and Fatal Crashes Per Year
250
175
100
Crashes/Years
0
90
180
270
360
Months
Increased penalties (Intervention 5)

FIGURE 11. SINGLE INTERVENTIONS (SOCIETAL HEALTH)



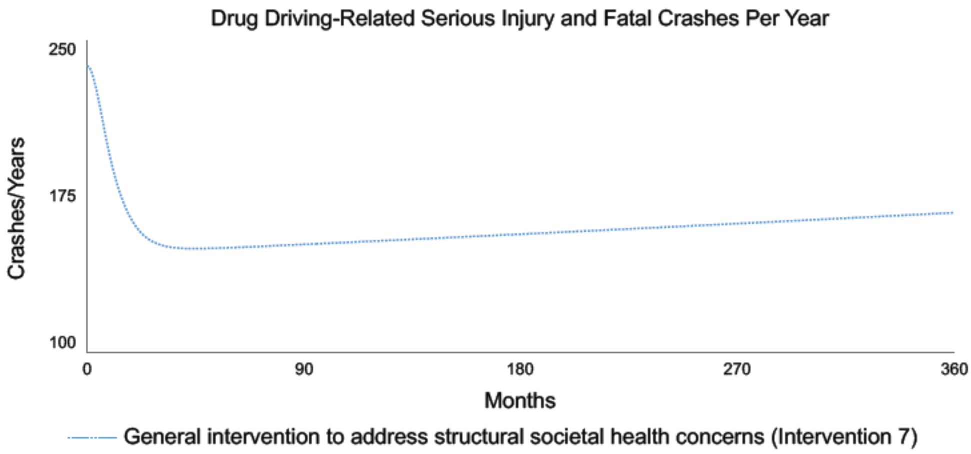
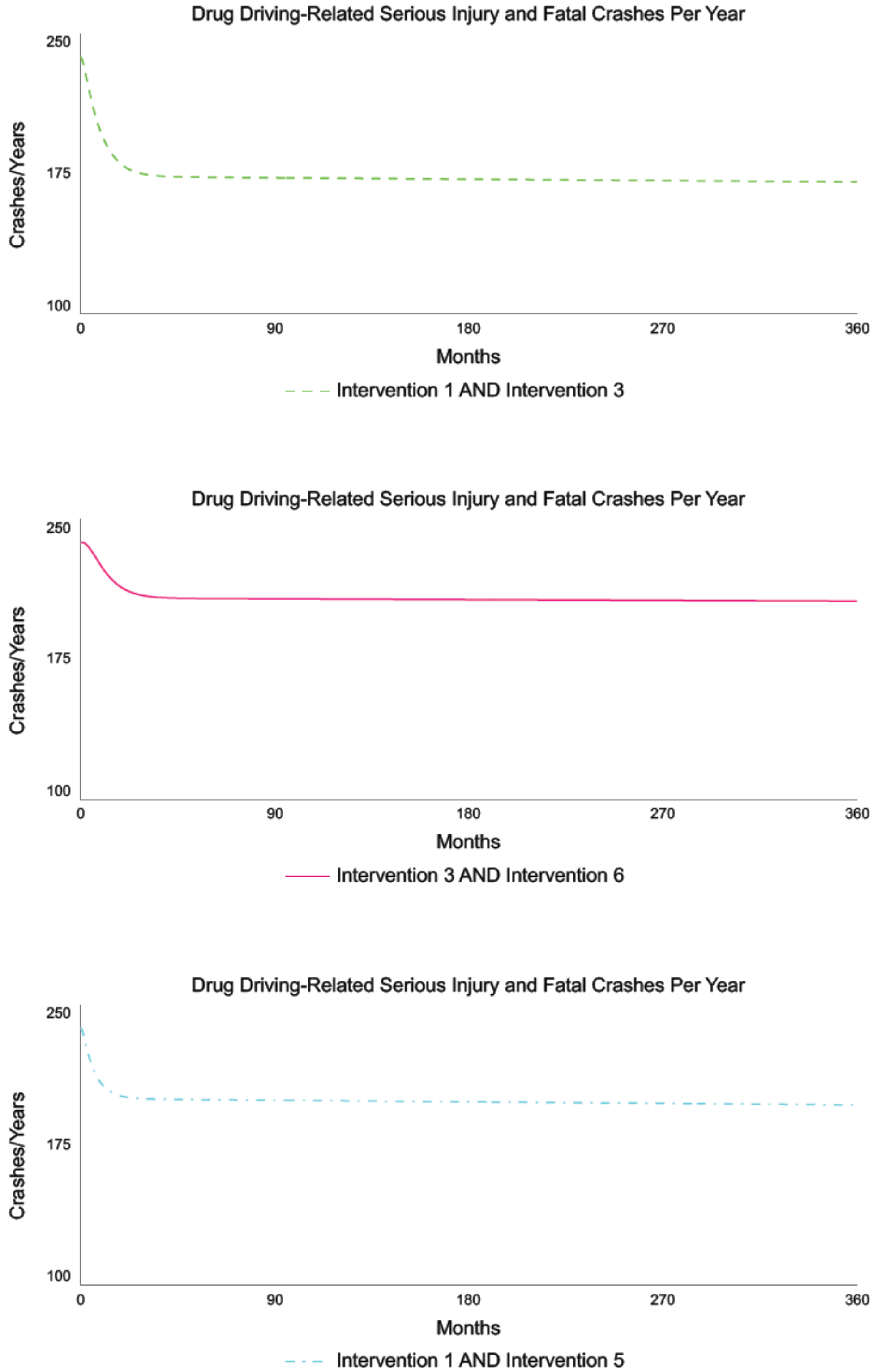


FIGURE 12. COMBINED INTERVENTIONS



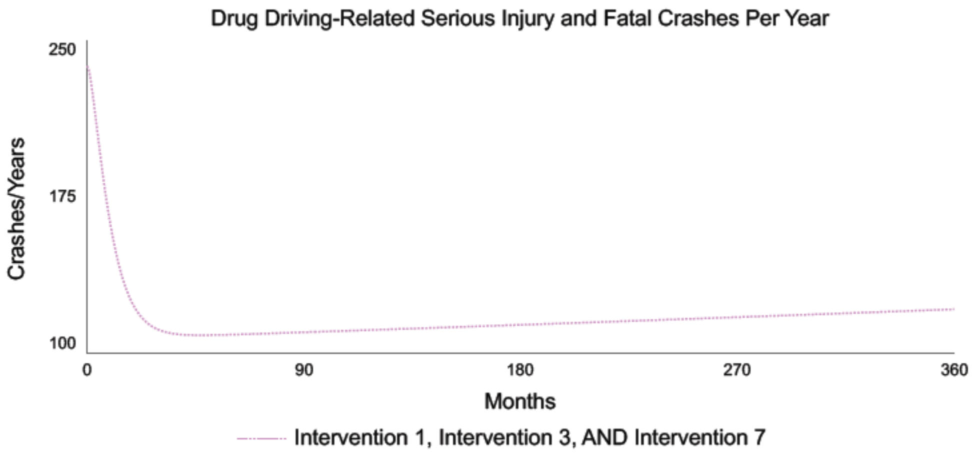

Drug Driving-Related Serious Injury and Fatal Crashes Per Year
250
175
100
Crashes/Years
0
90
180
270
360
Months
Intervention 1, Intervention 3, AND Intervention 7

TABLE 4. OUTCOMES OF THE DRUG DRIVING INTERVENTIONS TESTED IN THE SYSTEM DYNAMICS MODEL

	Intervention	Number of serious injury and fatal crashes	% change in the number of serious injury and fatal crashes from baseline
1	General roadside drug testing	196	-16.95
2	Mandatory curriculum-based education programs in schools	214	-9.32
3	Broad-based education campaigns for drug driving	205	-13.13
4	Roadside testing of impairment technology	196	-16.95
5	Increased penalties (fines and licence disqualification)	236	0.00
6	Health-based interventions for individuals with illicit substance dependence	237	0.00
7	General intervention to address structural societal health concerns	167	-29.24
8	Intervention 1 and Intervention 3	167	-27.54
9	Intervention 3 and Intervention 6	206	-12.71
10	Intervention 1 and Intervention 5	196	-16.95
11	Intervention 1, Intervention 3, and Intervention 7	121	-48.74

Section 6 | Key findings

This project adopted novel complex systems modelling approaches (CLD and SD modelling) to address gaps in the current knowledge base on drug driving-related road trauma and its prevention. Specifically, the project aimed to identify the set of interrelated factors responsible for drug driving-related road trauma in Queensland and (ii) examine the likely impacts of potential road safety interventions on the number of drug driving-related serious injury and fatal crashes in Queensland.

The CLD addressed the first study aim by providing a conceptual representation of the factors, and the interrelationships among the factors, that stakeholders perceive to contribute to drug driving-related road trauma. The CLD highlighted the complex, multifactorial nature surrounding drug driving-related road trauma, identifying a number of interacting factors relating to societal health, drug use across three distinct populations (recreational users, medicinal cannabis users, and persons with illicit substance dependence), drug control, road user behaviour, and the road safety response. The CLD, therefore, suggests that drug driving-related road trauma is not solely a product of the road transport system but is an issue that emerges from interactions among factors across the society, especially relating to societal health and drug use. A key observation from the CLD is the acknowledgement the issue of drug driving and drug driving-related road trauma is underpinned by a broader societal issue of drug use. According to the CLD, adverse societal health circumstances lead to more and more individuals using drugs to cope with or manage their stressors, increasing the number of individuals within the society who use drugs. This, in turn, increases the number of individuals who, intentionally or unintentionally, engage in drug driving and subsequently, the increases the number of drug driving-related crashes, injuries, and fatalities on the road. The observation that societal health drives population drug use is in line with the broader literature (e.g., Fergusson et al., 2008; Reed et al., 2007; Wahler, 2015); for example, that individuals who experience financial hardship or trauma are more likely to misuse drugs. Road safety authorities often attempt to address the issue of drug driving through road safety efforts (Razaghizad et al., 2021; World Health Organization, 2023); however, the CLD demonstrates that road safety efforts may have minimal effectiveness given the broader societal factors that contribute to drug use. It is suggested that an integrated public health approach is required to address drug driving. Indeed, research has demonstrated that an integrated approach to public health, urban planning, and road and transport safety generates greater gains in improving public health and road safety than a "siloed" approach (McClure et al., 2015). Road safety authorities should be working with others, including the police, doctors and other healthcare providers, pharmaceutical companies, to address drug use in the society, which will reduce the number of drivers driving under the influence of drugs.

The SD model addressed the second study aim by providing a quantitative representation of the CLD and enabling the ability to simulate the likely impacts of potential drug driving interventions on the number of drug driving-related serious injury and fatal crashes. Seven single interventions were tested, of which five targeted variables related to road safety (i.e., kilometres driven drug driving, the current proportion of the population who are drug drivers) and the remaining two targeted variables related to societal health (e.g., recovered persons with illicit substance dependence, individuals becoming persons with substance dependence). Outcomes from the single intervention simulations indicated that most of the road safety interventions tested resulted in a modest estimated reduction (9.32–16.95%) in the number of drug driving-related serious injury and fatal crashes, with general roadside drug testing and roadside testing of impairment technology yielding the greatest reduction. Increasing penalties, however, did not result in any estimated change in the number of drug driving-related crashes. Previous literature on the effects of increasing penalties has found little to no evidence for this intervention in reducing the occurrence of traffic offences (e.g., Briscoe, 2004a; Elvik & Christensen, 2007; Fry, 2023), though noting that this literature was focused on other adverse driver behaviour and not drug driving. Research has not been conducted to assess the effects of increasing penalties on drug driving and/or drug driving-related crashes. The intent behind increasing penalties is to deter traffic violations. According to the economic model of crime (Becker, 1968), offenders weigh the costs and benefits of committing traffic violations. An increase in penalties increases the expected cost of committing a violation, and this increase in cost is expected to deter violations. Evidently, this theory has not been supported by empirical evidence (e.g., Briscoe, 2004a; Elvik & Christensen, 2007; Fry, 2023). Other researchers have suggested that increasing penalties are ineffective because road safety authorities reduce other enforcement methods (e.g., roadside testing), keeping the expected cost of committing a violation constant ("game-theoretic model of crime and enforcement"; Tsebelis, 1990). When considering the effects of increasing penalties, other factors such as the certainty, severity, and swiftness of punishment should also be considered (Sakashita et al., n.d.). Outcomes from the single intervention simulations also indicated that, of the two interventions that addressed societal health, only the intervention that was aimed at addressing structural societal health concerns resulted in a large reduction (29.24%) in the number of drug driving-related crashes. This finding is expected, given the relationship among societal health, drug use, and drug driving. It is acknowledged that interventions that address structural societal health concerns may pose challenges in design, development, and implementation and will require a coordinated response from governments and policymakers. However, if implemented successfully, such interventions can have wider benefits, addressing both problematic drug use in the population as well as drug driving-related road trauma. The health-based intervention for individuals with illicit substance dependence resulted in no meaningful change in the number of drug driving-related crashes. The lack of impact from this intervention is likely due to it targeting the population of individuals with illicit substance dependence. This drug user population was estimated in the model to be the smallest in size compared to the other two drug user populations (e.g., medicinal cannabis users or recreational users). Thus, any impacts from interventions targeting this group alone are likely to be modest in terms of addressing the overall problem.

Four combined interventions were tested in the system dynamics model. Two of these combined interventions targeted only variables related to road safety (i.e., kilometres driven drug driving, the current proportion of the population who are drug drivers) and are considered single-domain interventions. Outcomes from the simulations indicated that although two interventions were combined, the estimated impacts on drug driving-related road trauma are comparable to a single intervention. For example, the combination of general roadside drug testing and broad-based societal health education campaigns for drug driving resulted in a reduction of 27.54% in the number of drug driving-related crashes while a single general intervention to address structural societal concerns resulted in a reduction of 29.24% in the number of crashes. The remaining two combined interventions tested in the system dynamics model targeted variables related to road safety and societal health and are considered multi-domain interventions. Outcomes from the simulations indicated that of these two combined interventions, the combination of general roadside drug testing, broad-based societal health education campaigns for drug driving and a general intervention to address structural societal concerns yielded the greatest reduction in the number of drug driving-related crashes (48.74%). This finding demonstrates the close links between road safety and societal health and how changes in societal health influence changes in road safety. The relationships between road safety and societal health can be leveraged to boost the effectiveness of interventions. Importantly, the testing of combined interventions also suggests that the effectiveness of interventions is not merely about the number of interventions combined but also on the domains or areas within the system that interventions should target to create the biggest change. It is argued that insights into relationships and leverage points can be gleaned using systems thinking-based methods and analysis, such as CLD and SD modelling. Multi-domain interventions are not often adopted to address road safety issues, most likely because the application of systems thinking is only emerging and the resources and close coordination among different government departments remain challenging. The project demonstrates that when addressing complex problems (e.g., drug driving), the application of systems thinking-based methods should be the norm and not the exception.

IMPLICATIONS

The findings strongly suggest that an integrated public health approach is required to address drug driving. In the context of drug driving, road safety stakeholders should coordinate their activities with those addressing drug misuse and substance dependence. Primary prevention efforts are likely to be effective through addressing the broader societal issues that result in drug use. Findings from our present study highlighted issues such as trauma and adverse incidents, cost-of-living pressures, social and work pressure, and lack of access to health services. Therefore, investment in policies that address these issues (e.g., supporting families and young people, reducing socioeconomic disadvantage, ensuring access to quality education, housing, and employment opportunities) can play an important role in reducing the likelihood of experiencing poor societal health or providing individuals with enhanced capacity to cope or manage with societal pressures. Further, affordable access to preventative healthcare and quality mental healthcare can support the prevention and early intervention of drug misuse and substance dependence.

In addition to primary prevention, coordinated strategies to address drug misuse and substance addiction should adopt a health and medical lens, as opposed to a criminal lens. This could involve more focus on early intervention and rehabilitation, supported by the police and justice stakeholders as individuals become known within the system. There is an opportunity for governments, the media, drug manufacturers, pharmaceutical companies, doctors, healthcare providers, road safety authorities and the police to work together address problematic drug use and reduce the number of drivers driving under the influence.

While integrated public health approaches are recommended, it is acknowledged that this is not straightforward, given that different stakeholder agencies have differing goals, approaches, funding sources and performance indicators. An important first step would therefore be to attempt to integrate the goals and approaches of key stakeholders within a coordinated approach. Without a coordinated systems approach to drug use more generally, interventions are likely to only have marginal impacts. It is therefore recommended that a whole of government approach to drug use is piloted. This could involve the stand up of a taskforce which brings together stakeholders from across government to address drug misuse, drug dependence and negative societal outcomes, including road trauma. The taskforce could develop a whole of government strategy focused on an integrated systems approach, including a coordinated set of action plans for implementation by each department (e.g. Queensland Health, Transport and Main Roads, Department of Justice). A formal evaluation of the taskforce could then inform future whole of government efforts that address other road safety issues impacted by societal issues (e.g. drink driving).

STRENGTHS AND LIMITATIONS

A notable strength of this project is the complex systems modelling methods used to investigate and address drug driving-related road trauma. The outputs of this modelling approach (conceptual representation of drug driving-related road trauma and simulation of intervention effects) have informed our collective understanding and undoubtedly, extended the knowledge base on this complex problem. Beyond this, it must be recognised that this method facilitated the participation and collaboration of stakeholders from a diverse range of expertise. It was apparent from the workshops held that stakeholders were able to identify and explain contributors to drug driving-related road trauma in line with systems thinking. The group modelling process undertaken in these workshops enabled deep discussions about the complexity behind drug driving-related road trauma and the resulting outputs reflected the stakeholders' collective understanding. Through this exercise, it was evident that to address the drug driving problem, a coordinated response from different government agencies, not just the road transport agency, is necessary.

This project was not without limitations. A limitation is the unavailability of data and evidence for input in the system dynamics modelling process. The modelling process required data from evaluations of interventions to estimate their effect size; however, this information is often unavailable for two main reasons. The first reason is that the data collected from interventions were not suitable for the purposes of the modelling exercise. For example, the primary intervention activities for drug driving are enforcement activities, specifically, targeted roadside drug testing. Data from these activities exist but they tend to focus on the number of positive drug tests detected and not the number of drug driving-related crashes (the outcome of interest). The second reason is that the interventions do not currently exist. Compared to drink driving interventions, drug driving interventions have not been widely explored and consequently, there is little data on the comparative effectiveness of different types of interventions (e.g., public health educational campaigns versus school programs). Although the deficiencies in data and data quality did not significantly affect our ability to simulate the likely effects of interventions, the simulations would produce more accurate estimates with better data inputs. Therefore, researchers and policymakers are encouraged to extensively evaluate and share evaluation findings of interventions to support future policy decision-making activities. Nevertheless, the model produced in this project remains a useful decision support tool for comparing the relative impacts of a variety of interventions to address drug driving-related road trauma.

CONCLUSION

This project adopted systems thinking approaches to understand and address drug driving-related road trauma in Queensland. The likely impacts of seven single interventions and four combined interventions on drug driving-related serious injury and fatal crashes were simulated over a 30-year time horizon via an SD model developed based on a CLD of drug driving-related road trauma in Queensland. Results from the simulation indicated that substantial reductions in crashes could be achieved through a combination of interventions that target road safety (i.e., general roadside drug testing and broad-based societal health education campaigns) and those that target societal health (i.e., general intervention that addresses structural societal health concerns). It is therefore concluded that a whole of government approach to the problem of drug driving is required, and that an initial important step is to establish an interdepartmental task force to explore the issue.

Appendix

TABLE A. FACTORS AND DEFINITIONS FOR THE CAUSAL LOOP DIAGRAM OF DRUG DRIVING-RELATED ROAD TRAUMA

Variable	Definition
Access to alcohol & drug services	The availability of alcohol and drug services offered to individuals to address their alcohol and drug use.
Access to diversion & support programs	The availability of alcohol and drug treatment or support programs offered to individuals who have been apprehended for drug offences from the criminal justice system.
Access to illicit drugs	The availability of illicit drugs that can be obtained by individuals for personal use or other purposes (e.g., distribution).
Access to medicinal cannabis	The availability of medicinal cannabis that can be obtained by individuals for medical purposes.
Alternative transport options	Alternative transport options that is not personal car use. For example, cycling, walking, skateboarding, or using public transport.
Commercial interest	Where individuals or entities receive a financial or commercial benefit from the outcome of decision-making.
Cost of living	The amount of money an individual needs to afford basic necessities (e.g., food, clothing, and housing).
Crashes	Collisions between two or more vehicles, or between vehicles and people, road infrastructure, natural hazards (e.g., animals, trees), or the built environment.
Degree of enforcement	The extent to which traffic laws are implemented and enforced to ensure the safety of all road users.
Education & awareness	Educational initiatives, campaigns, and programs aimed at informing and educating either the broader community or specific populations about the safe and compliant practices within the road transport system.
Funding for road safety initiatives	The amount of money allocated of the implementation of initiatives to improve road safety.
Illicit drug consumption	The administration or use of illicit drugs.
Illicit drug enforcement	The implementation of laws and actions by authorities to prevent the production, distribution, and use of illicit drugs.
Individuals engaging in drug driving	Individuals who drive under the influence of drugs (i.e., drive after using drugs).

Variable	Definition
Individuals under the influence of drugs	Individuals who have used drugs and are affected by their drug use.
Injuries & fatalities	The physical harm (hospitalised injuries) and deaths (fatalities) resulting from road safety incidents.
Media/social media reporting	The dissemination of content or information to a media or social media platform.
Misinformation	Information that is initially presented to be true or factual but later found to be false.
Perceived certainty of being caught	The extent to which an individual perceives that they will likely be caught for drug driving.
Perceived level of impairment	The extent to which an individual perceives themselves to be impaired (or unimpaired) in their ability to drive safely.
Persons with illicit substance dependence	Individuals who administer or use drugs repeatedly, resulting in tolerance, withdrawal, or compulsive drug use.
Political will	The commitment and follow-through of government leaders and policymakers to prioritise and take decisive action to address road safety issues (e.g., implementing effective policies, allocating sufficient budget and resources, enacting legislation)
Quality of urban planning/design	The standard to which urban environments are planned, constructed, and integrated with transport options to ensure safety, accessibility, and efficiency for road users.
Recognition of the problem	The awareness and acknowledgement by government leaders, policymakers, authorities, and the public of road safety issues, particularly issues that drive the gap between desired road safety goals and the current road safety status.
Recreational/incidental users	Individuals who, on occasions, use drugs for enjoyment or social acceptance.
Research	The systematic investigation to generate new knowledge to describe, explain, or predict the phenomenon of interest.
Resistance	The challenges that hinder the effective implementation of road safety policies and actions (e.g., public non-compliance, cultural attitudes, commercial interests/lobbying, institutional barriers).
Road safety policy action	The decisive action taken by government leaders and policymakers to implement a policy to address road safety concerns.
Shift to personal mobility devices	A preference for the use of personal mobility devices (e.g., e-scooters) over conventional forms of transport (e.g., cars, buses).
Social & work pressures	The actual and perceived expectations and demands individuals experience in their personal and professional lives. Such pressures may exceed individuals' capacity to manage them.
Societal acceptance of low-level drug use	Society's tolerance and approval of the use of small quantities of illicit drugs.

Variable	Definition
Societal health (physical/mental)	The overall physical and mental health and well-being of a society. Poor physical and mental health and well-being may result in individuals being prescribed with medicinal cannabis or 'self-medicating' with illicit drugs.
Supply of illicit drugs	The amount of illicit drugs being manufactured, misappropriated from health facilities, or imported into Australia, that is available for use.
Therapeutic drug consumption	The administration or use of medicinal cannabis that are prescribed by a health professional to manage or treat a health condition.
Therapeutic drug users	Individuals who are prescribed and use medicinal cannabis to manage or treat a health condition.
Trauma & adverse incidents	An event or a series of events that is experienced by an individual to be physically or psychologically harmful.
Use of health service	The use of a health service delivered by a health professional.
Workplace requirements for testing	Workplace programs that test employees for drugs, often due to legislative requirements or to manage work health and safety risks resulting from drug-related worker impairment.

Note. References to illicit drugs refer to the drugs listed in Queensland Government Drugs Misuse Regulation 1987.

TABLE B. VARIABLES, EQUATIONS, DATA, AND DATA SOURCES FOR THE SYSTEM DYNAMICS MODEL OF DRUG DRIVING-RELATED ROAD TRAUMA

Variable	Type	Equation/Data	Unit	Data sources
		Model sector: Alternative transport		
Available alternative transport capacity	Stock	Available alternative transport capacity (t–dt) + (new alternative transport capacity–capacity decline) × dt [Initial value = 1]	N/A	N/A
Capacity decline	Flow	Available alternative transport capacity × capacity decay	N/A	N/A

Variable	Type	Equation/Data	Unit	Data sources
New alternative transport capacity	Flow	Available alternative transport capacity × Appropriate urban planning/design × demand/need rate	N/A	N/A
Appropriate urban planning/design	Auxiliary	1 × demand/need rate	Unitless	Data unavailable/Not required for intervention simulation
Baseline service use	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Capacity decay	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Cost of living	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Demand/need rate	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Digital access factor	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Total alternative transport use	Auxiliary	Available alternative transport capacity × ((Digital access factor × Baseline service use)/Cost of living)	N/A	N/A
	Model sector: Drug control			
Illicit drug supply	Stock	Illicit drug supply (t–dt) + (New supply–Used supply) × dt [Initial value = 1,000]	N/A	N/A
New supply	Flow	((Manufacturing rate + Importation rate) × (1–Drug seize proportion)) × Demand	N/A	N/A
Used supply	Flow	Illicit drug supply × Percent used	N/A	N/A
Demand	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Drug seize proportion	Auxiliary	0.05	Unitless	Data unavailable/Not required for intervention simulation
Importation rate	Auxiliary	500	Drug units/Year	Data unavailable/Not required for intervention simulation

Variable	Type	Equation/Data	Unit	Data sources
Manufacturing rate	Auxiliary	500	Drug units/Year	Data unavailable/Not required for intervention simulation
Percent used	Auxiliary	0.95	Unitless	Data unavailable/Not required for intervention simulation
	Model sector: Policy resistance			
Policy resistance	Stock	Policy resistance (t–dt) + (Irritation–Habituation) × dt [Initial value = 1]	N/A	N/A
Habituation	Flow	Irritation	N/A	N/A
Irritation	Flow	DELAY1((Policy resistance × Road safety deterrence effect), 24)	N/A	N/A
	Model sector: Road safety			
Broad-based education effect	Stock	Broad-based education effect (t–dt) + (Implementation3–Depleting effect3) × dt [Initial value = 1]	N/A	N/A
Deterrence effect	Stock	Deterrence effect (t–dt) + (Implementation1–Depleting effect1) × dt [Initial value = 1]	N/A	N/A
School curriculum effect	Stock	School curriculum effect (t–dt) + (Implementation2–Depleting effect2) × dt [Initial value = 1]	N/A	N/A
Depleting effect1	Flow	Deterrence effect ÷ Decay1	Month	N/A
Depleting effect2	Flow	School curriculum effect ÷ Decay2	Month	N/A
Depleting effect3	Flow	Broad-based education effect ÷ Decay3	Month	N/A
Implementation1	Flow	DELAY1((Policy action × General testing × Targeted testing × Impairment testing × Increased penalties) ÷ Resistance multiplier, 3)	Month	N/A
Implementation2	Flow	DELAY1((Policy action × School curriculum), 3)	Month	N/A
Implementation3	Flow	DELAY1((Policy action × General education, 3)	Month	N/A

Variable	Type	Equation/Data	Unit	Data sources
Baseline active transport	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Baseline proportion of population who are drug drivers	Auxiliary	0.0865	Unitless	Royal Automobile Club Queensland (2024)
Current proportion of population who are drug drivers	Auxiliary	SMTH1((Baseline proportion of population who are drug drivers ÷ (Broad-based education effect × School curriculum effect)), 6)	Unitless	N/A
Decay1	Auxiliary	1	Month	N/A
Decay2	Auxiliary	1	Month	N/A
Decay3	Auxiliary	1	Month	N/A
Drug driving km per driver	Auxiliary	8,470	Km/Person/Year	Australian Bureau of Statistics (2020) estimates an average of 12.1 thousand kilometres travelled per vehicle per year. It was estimated that for drug drivers, they would drive 70% of the overall average.
Drug driving-related serious injury and fatal crashes per year	Auxiliary	Km driven drug driving × Serious injury and fatal crash risk per drug driving km	Crashes/Year	Unpublished data from Queensland Government Department of Transport and Main Roads indicates a total of 236 crashes in the calendar year of 2022.
General Education	Auxiliary	1.15	Unitless	Phillips et al. (2011) Yadav and Kobayashi (2015)
General testing	Auxiliary	1	Unitless	Data unavailable but it estimated that the effect size would not be larger than any other road safety interventions tested
Habitual drug drivers	Auxiliary	Current proportion of population who are drug drivers × (Societal health.Recreational users + Societal health.Medicinal cannabis	Persons	N/A

Variable	Type	Equation/Data	Unit	Data sources
		users + Societal health.Persons with illicit substance dependence)		
Impairment testing	Auxiliary	1.2	Unitless	Data unavailable, used data on sobriety checkpoints as proxy. Blais and Dupont (2005) Elder et al. (2002)
Increased penalties	Auxiliary	1	Unitless	Briscoe (2004b) Chow and Palamara (2015) Sohoni et al. (2020)
Km driven drug driving	Auxiliary	SMTH1(((Baseline active transport ÷ Alternative transport.Available alternative transport capacity) × (Drug driving km per driver × Habitual drug drivers)) ÷ Deterrence effect), 6)	Km/Year	N/A
Outrage factor	Auxiliary	SMTH1((Drug driving-related serious injury and fatal crashes per year ÷ Target), 12)	Unitless	N/A
Policy action	Auxiliary	Outrage factor	Unitless	N/A
Resistance multiplier	Auxiliary	Policy resistance.Policy resistance	Unitless	N/A
School curriculum	Auxiliary	1.1	Unitless	Elder et al. (2005)
Serious injury and fatal crash risk per drug driving km	Auxiliary	0.000000442	Unitless	It was estimated based on the total km driven drug driving (number of habitual drug drivers x drug driving km per driver = 531912764.5 km) and the number of drug driving-related serious injury and fatal crashes per year (236 in calendar year 2022).
Target	Auxiliary	236	Crashes/Year	Assuming no change in target from baseline. Unpublished data from Queensland Government Department of Transport and Main Roads indicates a total of 236 crashes in the calendar year of 2022.

Variable	Type	Equation/Data	Unit	Data sources
Targeted testing	Auxiliary	1	Unitless	Status quo
	Model sector: Societal health			
Medicinal cannabis users	Stock	Medicinal cannabis users (t–dt) + (New medicinal cannabis dependent users–Recovered medicinal cannabis users–No longer medicinal cannabis users) × dt [Initial value = 160,000]	Persons	Australian Institute of Health and Welfare (2024a)
People becoming substance dependent	Stock	People becoming substance dependent (t–dt) + (Becoming persons with substance dependence–New medicinal cannabis dependent users–New persons with illicit substance dependence) × dt [Initial value = 44,000]	Persons	Consensus estimate
People with illicit substance dependence	Stock	People with illicit substance dependence (t–dt) + (New persons with illicit substance dependence–New recovered persons with illicit substance dependence–Deaths) × dt [Initial value = 24,000]	Persons	Australian Institute of Health and Welfare (2024b) Queensland Health (2023)
Population	Stock	Population (t–dt) + (New people + Recovered medicinal cannabis users + Recovered persons with illicit substance dependence–Becoming persons with substance dependence–People dying) × dt [Initial value = 4,440,000]	Persons	Queensland population (aged 15 years and above) (eligible drivers) Queensland Government Statistician's Office (2023)
Recreational users	Stock	Recreational users (t–dt) + (New recreational users–No longer recreational users) × dt [Initial value = 550,000]	Persons	Australian Institute of Health and Welfare (2024b) Queensland Health (2023)
Becoming persons with substance dependence	Flow	((Trauma × Social and work pressures × Economic stress × Population × Natural drift) ÷ Access to health care) ÷ Structural health intervention	Persons/Month	N/A

Variable	Type	Equation/Data	Unit	Data sources
Deaths	Flow	Persons with illicit substance dependence × Death rate SD	Persons/Month	N/A
New medicinal cannabis dependent users	Flow	Proportion medicinal cannabis use × People becoming substance dependent	Persons/Month	N/A
New people	Flow	Population × Population growth factor	Persons/Month	N/A
New persons with illicit substance dependence	Flow	People becoming substance dependent × (1–Proportion medicinal cannabis use)	Persons/Month	N/A
New recreational users	Flow	((Population × New recreational drug rate × Societal acceptance × Availability of illicit drugs × Social and work pressures) ÷ Workplace requirements) ÷ Structural health intervention	Persons/Month	N/A
No longer medicinal cannabis users	Flow	Death rate MC × Medicinal cannabis users	Persons/Month	N/A
No longer recreational users	Flow	Recreational users × Recreational drug cease rate	Persons/Month	N/A
People dying	Flow	Population × Population death rate	Persons/Month	N/A
Recovered medicinal cannabis users	Flow	Access to health care × Medicinal cannabis users × Medicinal cannabis user recovery rate	Persons/Month	N/A
Recovered persons with illicit substance dependence	Flow	(Persons with illicit substance dependence recovery rate × Access to health care × Persons with illicit substance dependence) + Brief intervention conversions	Persons/Month	N/A
Access to health care	Auxiliary	1 ÷ Economic stress	Unitless	N/A
Availability of illicit drugs	Auxiliary	Drug control.Illicit drug supply ÷ Baseline	Unitless	N/A
Baseline	Auxiliary	1,000	Drug units	Data unavailable/Not required for intervention simulation
Brief intervention conversions	Auxiliary	Success rate × Number of road side detected	Unitless	N/A

Variable	Type	Equation/Data	Unit	Data sources
Commercial involvement	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Death rate MC	Auxiliary	0.02	Unitless	Consensus estimate
Death rate SD	Auxiliary	0.06	Unitless	Consensus estimate
Economic stress	Auxiliary	1	Unitless	Data unavailable/Not required for intervention simulation
Medicinal cannabis user recovery rate	Auxiliary	0.22	Unitless	Consensus estimate
Natural drift	Auxiliary	1/100	Unitless	Consensus estimate
New recreational drug rate	Auxiliary	2/100	Unitless	Consensus estimate
Number of road side detected	Auxiliary	400	Detections	Queensland Police Service (2024) reports 12,500 drug driving offences from roadside drug tests. Given the persons with illicit substance dependence (24,000 persons) in the drug use population, it was approximated that 400 of drug driving offences would involve persons with illicit substance dependence.
Persons with illicit substance dependence recovery rate	Flow	0.18	Persons/Month	Consensus estimate
Population death rate	Flow	0.019	Unitless	Consensus estimate
Population growth factor	Flow	0.02	Unitless	Queensland Government Statistician's Office (2024)
Proportion medicinal cannabis use	Flow	0.87 × Access to health care × Availability of illicit drugs × Commercial involvement	Unitless	Consensus estimate
Recreational drug cease rate	Flow	0.16	Unitless	Consensus estimate
Social and work pressures	Flow	1	Unitless	Data unavailable/Not required for intervention simulation

Variable	Type	Equation/Data	Unit	Data sources
Societal acceptance	Flow	1	Unitless	Data unavailable/Not required for intervention simulation
Structural health intervention	Flow	1.65	Unitless	Consensus estimation (It was estimated that this effect would be an aggregation of the intervention effects in the road safety model sector.)
Success rate	Flow	1.15	Unitless	Magill et al. (2019) Mun et al. (2021) Steinka-Fry et al. (2015)
Trauma	Flow	1	Unitless	Data unavailable/Not required for intervention simulation
Workplace requirements	Flow	1	Unitless	Data unavailable/Not required for intervention simulation

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Redaction Code 7, Redaction Code 8