



The Australian Prevention
Partnership Centre
Systems and solutions for better health

Building a compelling case for prevention

Computational modelling of health
and economic benefits of chronic
disease prevention interventions
in Australia

March 2019

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Computational modelling of health and economic benefits of chronic disease prevention interventions in Australia

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Key points

- We have built a proof-of-concept demonstration of the potential of dynamic simulation methods to show how several modifiable risk factors interact, and the impact of a range of interventions on both risk factor prevalence and health and economic burden.
- Existing modelling can forecast the health burden of chronic diseases and the impact of individual risk factors, but it does not consider what happens in the real world – for example, how interventions work in combination, or how people live with multiple risky behaviours that jointly influence the same preventable chronic disease.
- Prevention Centre policy partners are invited to engage with our online simulation interface to simulate policy experiments.
- The next phase of the project is to develop the proof-of-concept model into a robust decision-support tool for policy makers.
- This model requires further development before it is suitable for informing investment decisions.

Summary

The Compelling Case for Prevention project is a proof-of-concept demonstration of the potential of dynamic simulation methods to provide an engaging and useful tool that illustrates the health benefits and economic value of prevention interventions for the population, the health system and Australian productivity.

One of its major technical innovations is the integration of participatory conceptual mapping and computational modelling at the national and state and territory levels. Using a dynamic population, as opposed to a static cohort, the model can demonstrate the interactivity of several modifiable (behavioural and metabolic) risk factors, and the impact of a range of interventions on both risk factor prevalence and health and economic burden.

The Australian Prevention Partnership Centre (the Prevention Centre) has taken a participatory approach to the development of models in this project by facilitating workshops to map the complex system that is preventable chronic disease in Australia. The process involved many of our Prevention Centre policy partners, who contributed to this system mapping and subsequent model development and prioritisation of strategic interventions.

The national system dynamics model computes disability-adjusted life years (DALYs), healthcare costs and productivity costs due to six key risk factors – tobacco, harmful alcohol consumption, physical inactivity, high BMI, overall dietary risk and high blood pressure. Input data on the strength of association between risk factors and diseases was obtained from the Global Burden of Disease Study 2016, published in *The Lancet*. The attributable disease burden reported by the model was subsequently calibrated with GBD 2016 and demonstrated high levels of consistency.

One of the aims of the project was to develop a tool that calculates the cost-effectiveness of prevention interventions, alone or in combination, in terms of forecasted discounted net benefits over future decades.

A participatory workshop followed by individual interviews with interested public health academics provided technical advice to support the selection and definition of five prevention strategies that could be assessed using the model to demonstrate their costs and benefits on Australia's burden of disease at a population level. To demonstrate the varying dynamics of potential interventions, a range of strategy types were included, from regulation and pricing, to social marketing, and secondary prevention or screening.

This model is still a work-in-progress and should not be used to inform investment decisions. However, an initial online simulation interface has been developed to allow Prevention Centre policy partners to simulate policy experiments using the limited interventions already included in the model structure. Users of the interface are able to understand the assumptions behind these interventions, adjust them if required, and explore the costs and benefits of the impact of these strategies over time and on a number of health or economic indicators.

In addition, three agent-based models of priority issues to our policy partner, ACT Health, were constructed: smoking behaviour and environmental restrictions, excessive alcohol consumption and the food legislative environment.

Discussions with current and potential project collaborators have indicated interest in extending the model to include more detail on the social determinants of health and distributional effects of interventions to reduce inequalities, and to draw wider and deeper participation across other sectors, for example education or urban planning. These suggestions, with future funding from the Prevention Centre, have the potential to take this proof-of-concept chronic disease system dynamics model towards its realisation as a health policy decision-support tool.

Introduction

The Prevention Centre worked in partnership with Deakin University to produce a proof-of-concept dynamic simulation model that both quantifies preventable chronic disease harms and demonstrates the health and economic value of selected real-world interventions (alone or in combination) on a dynamic Australian population. This report provides an overview of the progress of building the model and some initial insights from it. It does not contain a full list of variable estimates and assumptions, model source code or structure. The online digital simulation of this model contains further details and can be made available to Prevention Centre partners on request.

Part of the challenge of communicating the importance of preventing chronic disease is the ability to describe the big picture of prevention. This project, 'Building the Compelling Case for Prevention'¹ had at its core the novel idea that a digital tool could assemble, calculate, forecast and communicate in one place the best available data and evidence on the preventable health and economic burden and explore, by virtual experiments, where the best health gains and cost offsets could be achieved in a simulated population.

The 2016 edition of the Global Burden of Disease study found:

- That 36% of the health burden in Australia was attributable to modifiable risk factors²
- Smoking was linked to 58 diseases and injuries, causing 22,200 deaths and 7.9% of disability-adjusted life years (DALYs).² Twelve percent of Australians over the age 14 were daily smokers³
- Alcohol consumption was linked to 39 diseases and injuries causing 8,100 deaths and 5.4% of all DALYs.² And 17% of Australians consumed alcohol at levels placing them at lifetime risk of an alcohol-related disease or injury³
- Overweight and obesity was linked to 37 diseases and injuries causing 18,200 deaths and 8.3% of all DALYs.² Close to two-thirds of Australian adults and 1 in 4 Australian children were overweight or obese in 2014–15 and 28% of Adults were obese³
- Dietary risk factors combined were linked to 49 diseases and caused 27,500 deaths and 7.9% of DALYs.² In one measure of poor diet, 96% of Australian adults did not consume adequate vegetables³
- Physical inactivity was linked to five diseases and caused 5,200 deaths and 1.2% of DALYs in 2016.² And 54% of women and 51% of men aged 18–64 years were inactive or insufficiently active.³

Several studies have previously tackled economic modelling of chronic disease, primarily around obesity or other single risk factor health impacts. In Australia, the **ACE-Prevention project** developed an approach to evaluate the benefits of more than 150 interventions using comparable methods of economic analysis.⁴ This method has subsequently been applied to obesity policy interventions and in international settings.⁵ However, this method, while applying standardised evaluation methods across interventions, is limited in its capacity to account for a dynamically changing health situation with interacting components over a long time-horizon.

Homer et al^{6,7} developed a system dynamics approach, **Prevention Impacts Simulation Model (PRISM)**, to simulate the effect of clinical and population-level interventions to reduce a range of environmental and behavioural risks for CVD events and several other related chronic conditions using a dynamic population. Incorporating population dynamics - birth rates, death rates, emigration and immigration – a system dynamics simulation captures stocks of sub-populations in various health or risk factor states or disease progression and calculates the economic values of these stocks. Estimating the flows into or out of these stocks and initial stock values, a computer simulation calculates a set of differential equations updating the stock variables through time increments, until the final time horizon is reached. (Refer to the Glossary for further explanation of these system dynamics terms). Similarly, in Australia system dynamics models of single risk factors for chronic disease have been recently developed and begun to be published.^{8–10}

Both modelling approaches, typified by ACE-Prevention and PRISM, have the potential to support state/territory and federal health officials to build the evidence for investment policy in chronic disease prevention. However, the most recent Australian economic study of the impact of reducing multiple risk factors was completed by Deakin Health Economics for VicHealth in 2009.¹¹ This analysis used a traditional cohort approach to model a static population over their lifetime.

The Prevention Centre aimed to build upon these American and Australian computer simulation modelling approaches to chronic disease prevention and develop an up-to-date Australian digital learning tool, using a simulated Australian population together with economic analysis of new or hypothetical prevention interventions developed through the ACE-Prevention program. This Prevention Centre project intended to:

- Demonstrate the benefits of dynamic simulation modelling to better guide resource allocation in prevention and maximise the health of the Australian population
- Build support for the prioritisation of the prevention of lifestyle-related chronic disease at the government level.

The project aimed to deliver a proof-of-concept, national model of six interacting lifestyle risks and 10 linked diseases with the ability to forecast health and economic burden over time. It also aimed to link five intervention types to demonstrate net benefits over the same time horizon and build an economic case for government to invest further in prevention. It aimed to demonstrate the use of more textured individual level or agent-based models (ABM) for specific identified risk behaviours at the state or regional level and how these models could interact with the national model to track impacts on local and national performance. Three ABMs of single risk factor behaviours of priority to the ACT Government were simultaneously developed to inform chronic disease policy development in the ACT.

Since 1990, the Global Burden of Disease (GBD) study has collected population health data to provide a comprehensive tool that can quantify the risk factors and diseases that cause death and disability across the globe, by country, in order to understand health trends over time. The GBD data for the Australian population remains the most recent comparative risk analysis. The data was readily available for this project and was used as a historical calibration tool over the previous five years.* (See Modelling methods, page 10).

This project demonstrates the innovative integration of participatory conceptual mapping and computational modelling at the national and state levels. The Compelling Case for Prevention project is a proof-of-concept demonstration of the potential of dynamic systems simulations to provide an engaging and useful tool that can show the economic value of investment in specific prevention interventions to reduce lifestyle-related harmful behaviours to individuals, the health system and Australian productivity.

This national system dynamics model can estimate the relationships between six key modifiable risk factors (tobacco, physical inactivity, harmful alcohol use, high body mass, poor diet and high unmanaged blood pressure), and their changes in prevalence with associated health burden and to health system costs and productivity costs.

Initially 'dietary risks/poor diet' was considered a priority behavioural risk factor for inclusion in this model, given its high ranking in the GBD study, globally and in Australia. However, difficulties with the nutritional epidemiology of this risk factor, (with 13 separate micronutrient components of poor diet identified), the complexities of nutrition dynamics, and the inability to reliably calibrate the prevalence of this risk factor in Australia over time, led to its limited inclusion. Individual dietary risks have not been included, however the impact of poor diet on BMI (expressed as population-level excess kilojoule intake) as a hypothetical scenario that reduces excess kilojoule intake, is demonstrated in the intervention module.

* The Australian Burden of Disease Study produced by the AIHW has only published data for 2003 and 2011. After the completion of this modelling project, 2015 data (mortality only, required to calculate YLL's) became available. The ABDS YLD and DALY data for 2015 should become available in late 2019, potentially enabling a revision of our system dynamic model (allowing for resolution of aggregation and classification differences).

'High unmanaged blood pressure' was later added to the model as a modifiable metabolic risk factor to complete the risk factor mix. This risk factor drives much of the cardiovascular disease burden calculation in this model, which in turn represents a high proportion of non-communicable diseases.

The model synthesises the research evidence related to the above risk factors and their contribution to disease burden to estimate the cost-effectiveness of selected hypothetical and simulated prevention interventions. Key features of this simulation include:

- A system dynamics approach to modelling the national population over a 40-year time horizon
- A range of modifiable risk factors included
- All major non-communicable disease groups included, with reference to the Global Burden of Disease Study (2016), however diseases burdens are not linked to risk factors at this stage of the project
- Four real-world risk factor national intervention strategies that can be switched on or off, that demonstrate a range of intervention types. These were scoped and simulated in order to test intervention implementation dynamics of health and economic outcomes. An additional intervention (screening) simulates prevention impact at a disease level. One intervention (tobacco) also captures results from the agent-based model of smoking restriction and builds this into the national system dynamics model
- Three separate agent-based models of single risk factors and policies for the ACT Government.

These features enable the simulation to:

- Assess the potential health and economic benefits of reducing the prevalence of individual and combinations of risk factors by seeing how different scenarios of risk factor reduction and intervention effectiveness impact these outcomes
- Test the impact of new or scaled-up prevention approaches individually or in combination with other interventions related to one or more modifiable risk factor (using the model as an analytic tool)
- Test the sensitivity of several key variables or assumptions around intervention implementation.

The system dynamics model has an open, transparent structure that allows users to contest assumptions by adjusting key variables and understand the mechanisms of the dynamic systems via the interface. These inputs may be varied for many reasons including, a lack of research consensus on intervention effectiveness or implementation practice (in relation to both the costs and benefits), timing of implementation and differences in population characteristics.

Literature reviews

To support the project, two systematic reviews were undertaken.^{12,13} The purpose of the **first systematic review** was to establish the evidence-base on the health burden caused by modifiable risk factors in Australia, with a focus on the lifestyle risk factors prioritised for inclusion in the model. This allowed us to identify where there was consistency in the estimates of attributable burden, where there were discrepancies and gaps in evidence, and to identify the methods that have been used in these analyses. This information provided several functions in the context of the Compelling Case for Prevention project:

- It established what we currently know about the degree of preventable health burden and the quantitative estimates from this evidence can be used to help communicate the case for prevention
- The included studies provided a wealth of input data and methodological approaches that contributed to the development of the model. For example, by establishing that the Global Burden of Disease study was the latest and most comprehensive analysis to date, data from this study could then be used to inform and calibrate the model
- Current evidence in combination with the model provided a comprehensive suite of evidence establishing the need for action and potential benefits of prevention interventions. Findings of the review included ascertaining that dietary risk factors accounted for the greatest number of preventable deaths in Australia and that tobacco smoking still contributed for the greatest number of disability-adjusted life years (DALYs), despite the recent reductions in the prevalence of smoking. The full results of this study have been accepted for publication in a peer-reviewed journal.

The **second systematic review** focused on the economic burden caused by preventable risk factors in Australia. There are four main areas of monetary impact associated with preventable disease:

- The most obvious opportunity for reducing the costs of non-communicable disease associated with modifiable risk factors is the healthcare costs associated with diagnosing and treating disease once it occurs. However, there are other substantial costs to consider
- The non-health care costs to government, reduced tax receipts due to lower workforce productivity, and costs incurred by the criminal justice system
- Preventable disease causes economic production impacts due to time off work, premature retirement and death, and reductions in home-based and leisure-based production. There are also impacts to the wider economy represented by macroeconomic measures such as GDP and balance of trade
- Health impacts can be monetised to calculate an overall net monetary impact of preventable disease.

This review served similar functions to the first review in the context of the Compelling Case for Prevention project, in that it established the current state of economic evidence, informed the development of the model and provided a comparison to outputs of the model. Findings of this work included estimates of economic burden in the billions of dollars attributable to each prioritised risk factor across multiple studies. Production and non-health costs to government were often much larger components of economic cost compared with healthcare costs alone. A number of scenarios of the health and economic benefits of reducing the prevalence of risk factors were also identified and summarised.

The results of this study will be submitted to a peer-reviewed journal for future publication and used to communicate the economic imperative for taking action to reduce the prevalence of modifiable risk factors.

Modelling methods

This section will focus on the approaches used to develop the national system dynamics aggregate model, the core component of this project. Development of the three ACT agent-based models is discussed on page 19.

Model development process and participatory approach

The building of the dynamic simulation national population model was guided by a participatory evidence synthesis process. A multidisciplinary group of Prevention Centre funding and policy partners, including chronic disease advocates, policy agencies, university academics, health promotion organisations, as well as international leaders in dynamic simulation modelling were invited to contribute to this work as part of the expert model building group (see [Appendix A](#) for a list of participants and core project team members).

Based on a long history of applying participatory approaches to the process of building simulation models (primarily system dynamics modelling in non-health sectors), modelling experts have developed guidelines and frameworks to support good practice in working with small groups to facilitate model conceptualisation, formulation, quantification, calibration and validation, as well as conducting policy analysis/simulation experiments.^{14–16} The processes used to facilitate the model building workshops drew on these established procedures.

Two participatory workshops were conducted, on 6 June 2017 and 20 February 2018, with between 30 and 40 stakeholders attending each. The first workshop aimed to introduce participants to system dynamics, define the boundaries of the problem and begin to map a conceptual diagram. In the workshop, research partners collaboratively mapped and agreed on the key drivers and influencers on chronic disease in Australia. The second workshop provided an opportunity for this same stakeholder group to understand the core structure of the system dynamics model, then prioritise and map the mechanisms by which selected interventions impact risk factors of interest and therefore chronic disease burden in Australia.

In addition, individual interviews were conducted with relevant expert subject stakeholders who acted as key informants and advisers to the intervention scope, definition and refinement processes.

Key achievements of the workshops include:

- Introduction to dynamic simulation modelling and application of dynamic simulation modelling methods, discussion of economic outputs of relevance to stakeholders and how these are applied to understanding and capturing the preventable component of the chronic disease burden
- Collaborative development of the underlying structure of the model and mapping of the most important factors driving preventable chronic disease
- An update of the core structure of the model and a facilitated discussion and initial development of potential interventions and strategic policies for inclusion in the demonstration national system dynamics model.

During this model development period, the modelling team also held smaller workshops and discussions with key ACT Health managers over the design and implementation of interventions to be modelled in the three agent-based models of smoking, alcohol consumption and food policy environment for the ACT population.

Developing the conceptual model

The first step in constructing the quantified computational model was to develop a conceptual model of the relationship between chronic disease and the social, economic and environmental drivers over the life course. In the early stages of the process, the complex interactions of the relationship between (modifiable)

risk factors, their diseases and the systems were defined and then constructed by the core model building team. Subsequently, the modelling team converted the map into a conceptual model of the problem, **Figure 1**, using Insight Maker software (<https://insightmaker.com/>).

The conceptual map was jointly produced by the team members, based on the core components of the preventable chronic disease system which were most relevant to the problem domain, i.e. the projected health and economic burden of disease, related healthcare costs and lost productivity over time. This was a reflection of the priorities and interactions observed and sketched by the wider stakeholder group during Workshop 1 (2017). This conceptual model formed the basis of development of the computational model.

Building the proof-of-concept computational model

The conceptual model of the preventable component of chronic disease was developed into a computational simulation model through an iterative process of model conceptualisation, quantification of parameters and representation of the mathematical relationships among the components of the logical structure. The conversion to a computational model drew on published conceptual understandings of risk factor behaviour incorporating chronic disease progression, published research and expert consensus to arrive at a plausible and testable representation.*

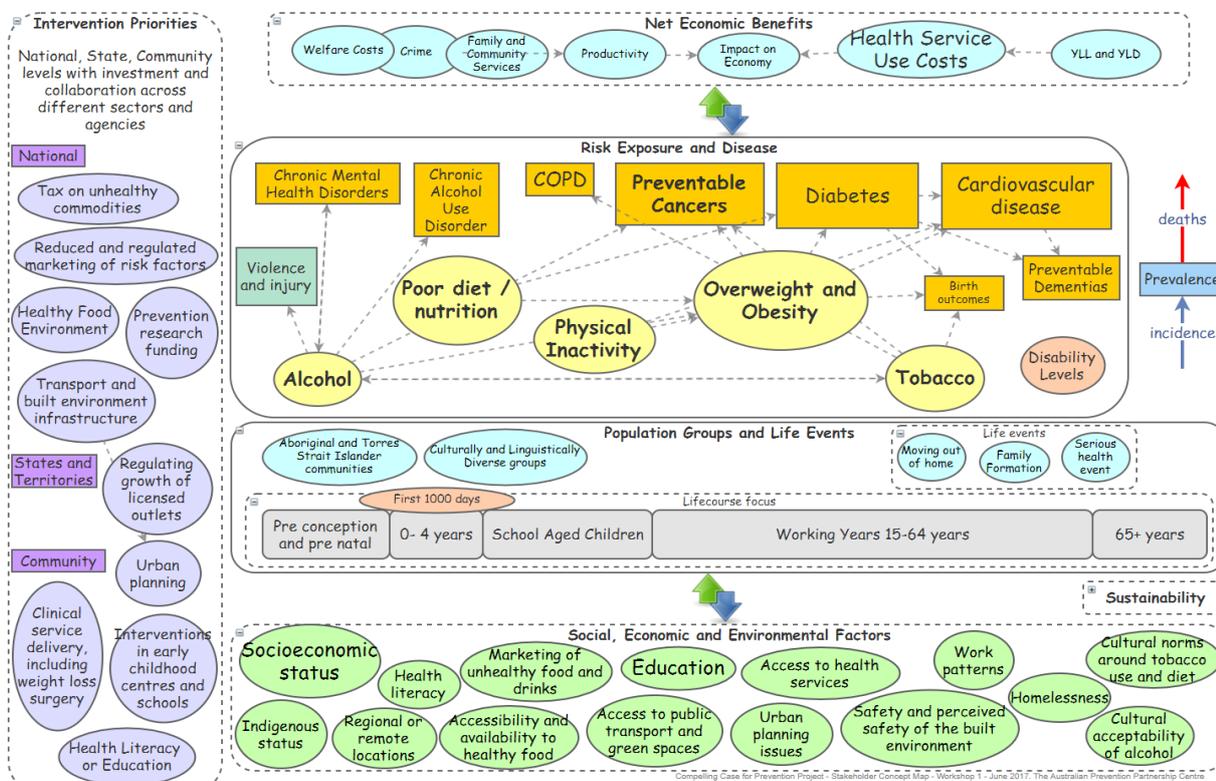


Figure 1: Conceptual model of preventable chronic disease, produced November 2017

* This mainly included the GBD Study 2016 methodology, available at <http://ghdx.healthdata.org/gbd-2016/data-input-sources>. The modelling team also drew on their own published models relating to single risk factor and chronic diseases.^{8,9,10} It also drew on healthcare service pathways modelling work seen in A decision support tool to inform local suicide prevention activity in Greater Western Sydney (Australia).

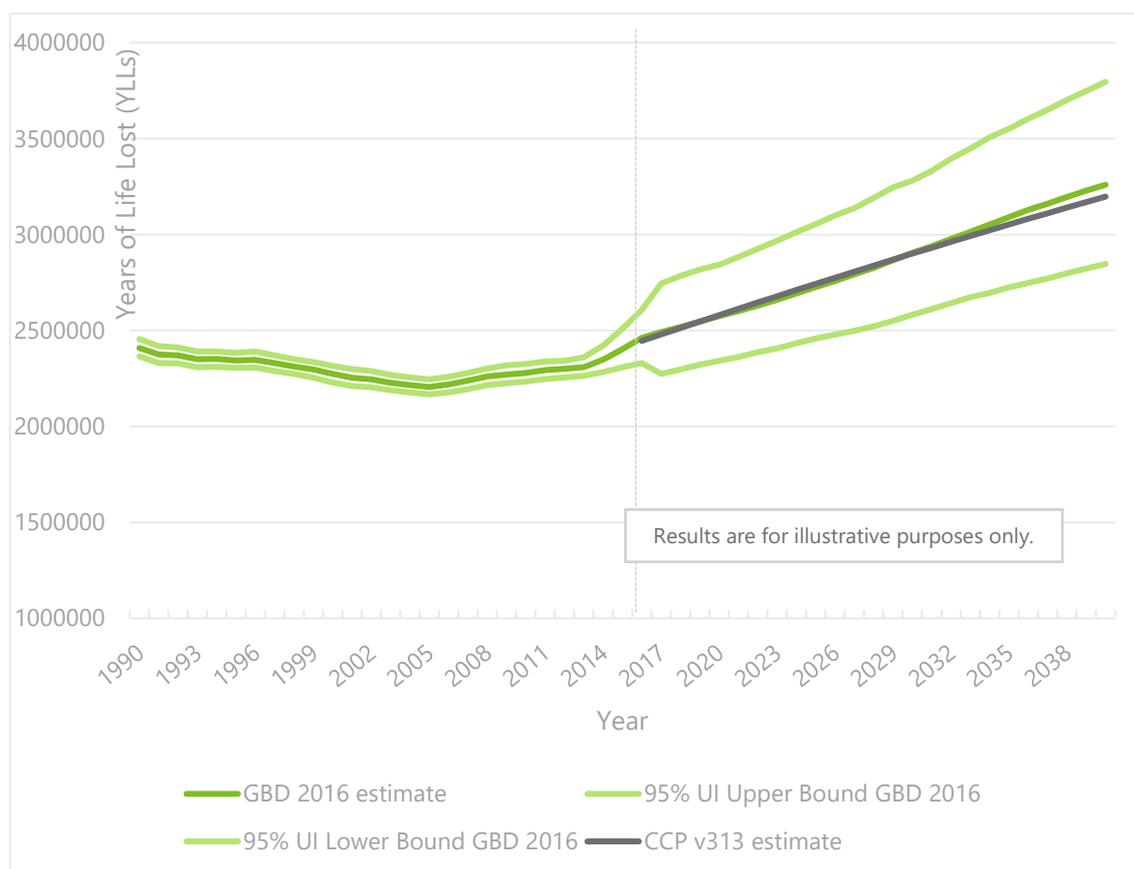


Figure 2: Forecasted years of life lost for Australia – GBD 2016 estimate compared with Compelling Case Project (v313). 95% Uncertainly intervals are for the GBD 2016 estimate

The core structure of this proof-of-concept computational model links a synthesised open population of Australia and its ageing dynamics with risk factor prevalence and trends, prevention interventions of interest and major disease groups.* It was iterated over several months in order to produce a structure that both aligned with risk factor and non-communicable disease progression over time and matched GBD disability-adjusted life year (DALY) results and years of life lost (YLL) forecasts. **Figure 2** provides an example demonstration of this functionality.

The GBD study provides a useful baseline by which the team could measure and calibrate the current status of diseases (or ‘causes of burden’, according to the GBD) and quantified burden in order to support the model’s validity for future forecasts of proposed intervention impacts.

The GBD Study updates its data results comparison tools each year to produce forecasted mortality estimates for around 250 diseases up to the year 2040, based on previous years all-cause mortality and a number of independent variables and time, as well as an estimate of premature mortality or Years of Life Lost (YLL), by cause, risk factor and country.¹⁷ YLLs, as a core component of DALYs, are integral to the basic structure of this project’s Compelling Case aggregate model. **Figure 2** above demonstrates the consistency of forecasted YLLs between this project’s aggregate model and the GBD modelling tool itself.

However, where the GBD study data has the capability to also forecast health burden by disease and risk factor, it has limited ability to account for real world implementation effects of simulated interventions, disease and intervention implementation lag onset, intensity of the risk factor in question and the likely co-

* Major disease groups are labelled ‘causes of burden’ in this model to ensure consistency with the classification in the GBD Study.

morbidities of risk factors, that is, the recognition that people live with multiple risky behaviours that jointly influence the onset and progression of the same preventable chronic disease. These are the type of complexities that a multi-method simulation model of preventable chronic disease has the potential to accommodate, and some of the key priorities to address in this project.

The behaviour of the dynamic system of chronic disease prevention and progression over time is displayed graphically by the computer modelling engine (Stella Architect®), solving a set of differential equations using integration approximation and other numerical analysis techniques. The draft model was progressively refined over multiple iterations with policy experts (through workshops and discussions) and investigation of differences between the model forecasts and observed historical outcomes in the GBD, using 2011 and 2016 Australian results as reference points. The model was calibrated using statistical estimation techniques, refined, and improved by a continual feedback process. The product of this process is an interactive dynamic simulation model capable of forecasting the likely impact of interventions over time, either individually or in different combinations.

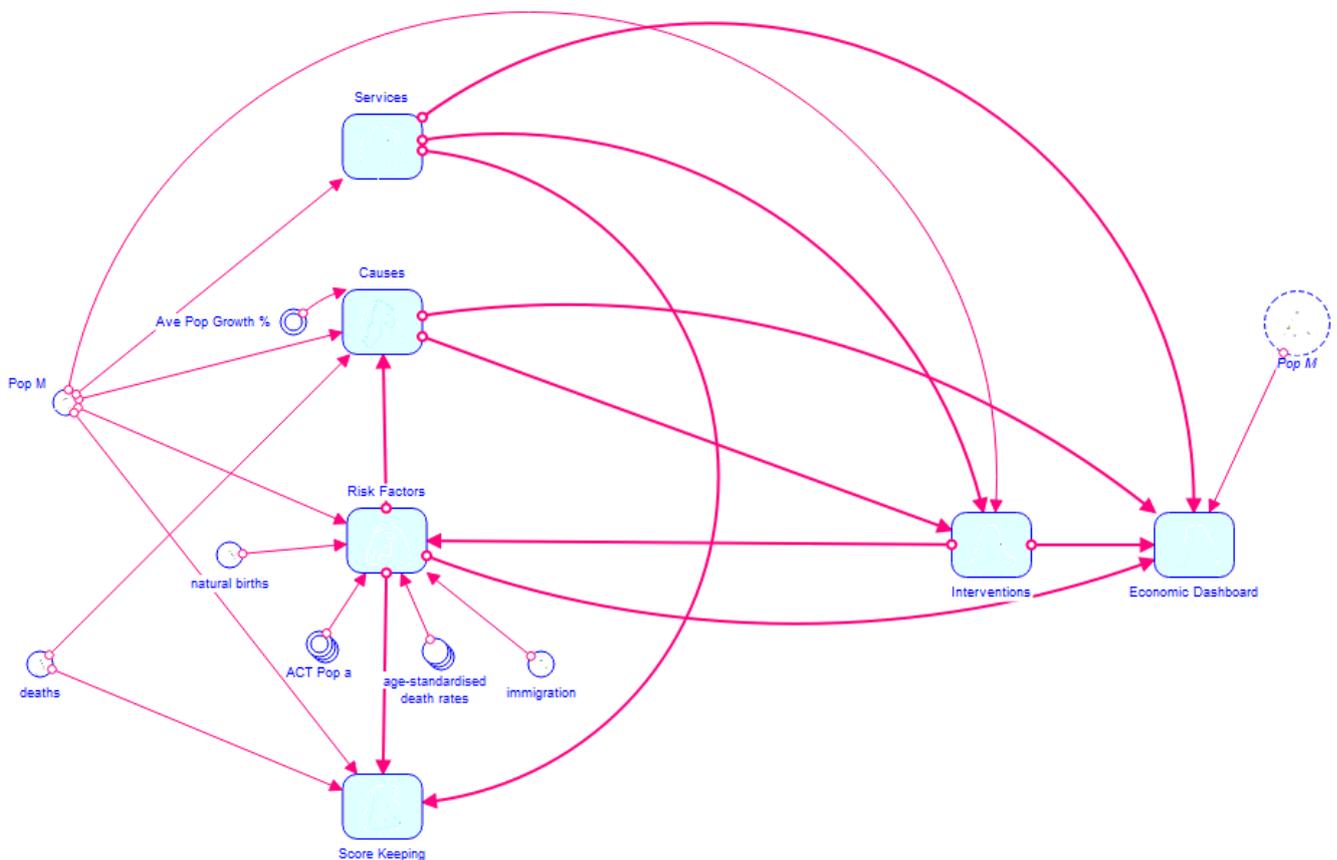


Figure 3: Preventable non-communicable disease burden: core model architecture highlighted in blue

Figure 3, above, shows the modular core model architecture of this national system dynamics model. The diagrammatic software in the model source file uses modules as an organisational tool to provide hierarchical connections throughout the system being described. Each highlighted square module represents up to four sub-layers of model structure of the system. For example, the 'Risk Factor' module includes four sub-modules each describing 'Environmental Risks', 'Behavioural Risks', 'Metabolic Risks' and a further module links these risk groups to disease burden calculations. Within the 'Behaviour Risks' module lies another three modules and self-contained model structure for 'Tobacco Use', 'Physical Inactivity', 'Alcohol Use'. The 'Metabolic Risk' module contains two sub-modules 'High Blood Pressure' and 'Body Mass'.

Figure 4 (page 15) provides an example of the national system dynamics model architecture. This structure for calculating tobacco use dynamics in the ACT population demonstrates the integration of ABM results in the aggregate system dynamics model structure. This component is located within the national tobacco use sub-module, which is situated within the behaviour risk factors module which links to the core model structure indicated in Figure 3. Single risk factor model architecture is replicated for high body mass, risky alcohol use, high blood pressure and physical inactivity in other model modules.

The delimitation of major non-communicable disease groups and calculation of respective health burdens in the model can be seen in **Figure 5** (page 16). This model structure is located within the overall 'causes of health burden' module which calculates overall DALYs and links to the intervention modules and economic costing module, as seen in Figure 3. Each disease group module, as highlighted in blue in this figure, calculates disease progression, treatment, burden and death.

The overall model structure file produced using Stella Architect is linked to a digital interface file that allows for user-friendly interaction and testing of model assumptions and hypothetical policy scenarios.

Readers and users of this model interface will note that not all the prioritised drivers or factors influencing preventable chronic disease in the conceptual model (Figure 1) have been transferred into the proof-of-concept computational model structure. There were limitations in the extent to which social, economic or environmental factors could be integrated and 'dietary risks (poor diet)' was removed as a priority risk factor for interaction and testing at this stage, although its contribution as a single risk factor to the overall non-communicable disease burden is included in the DALY calculation. Additionally, sub-population analysis has not been fully realised yet. These considerations may be explored in further stages of model development.

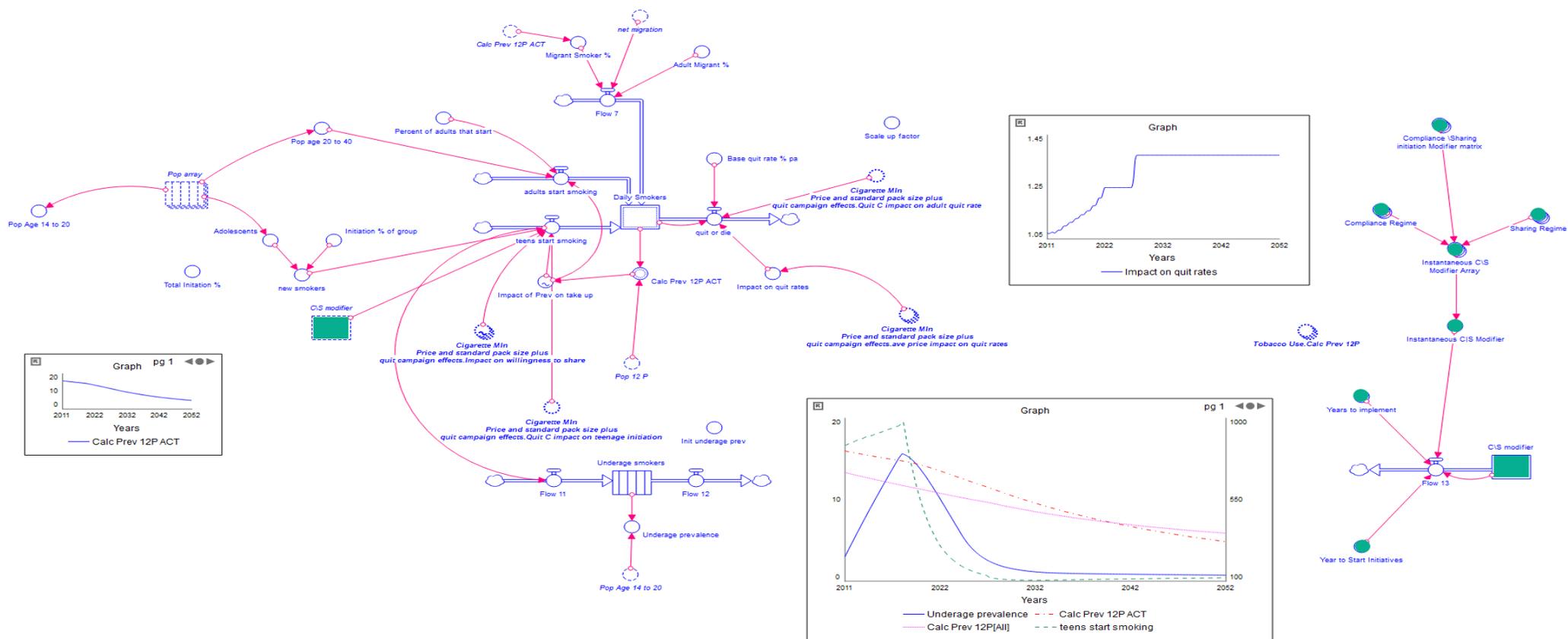


Figure 4: Sub-module system dynamics model architecture for the behavioural risk factor tobacco use – ACT sub population only – demonstrating integration of smoking agent-based model results as parameters (highlighted in green) with national tobacco interventions

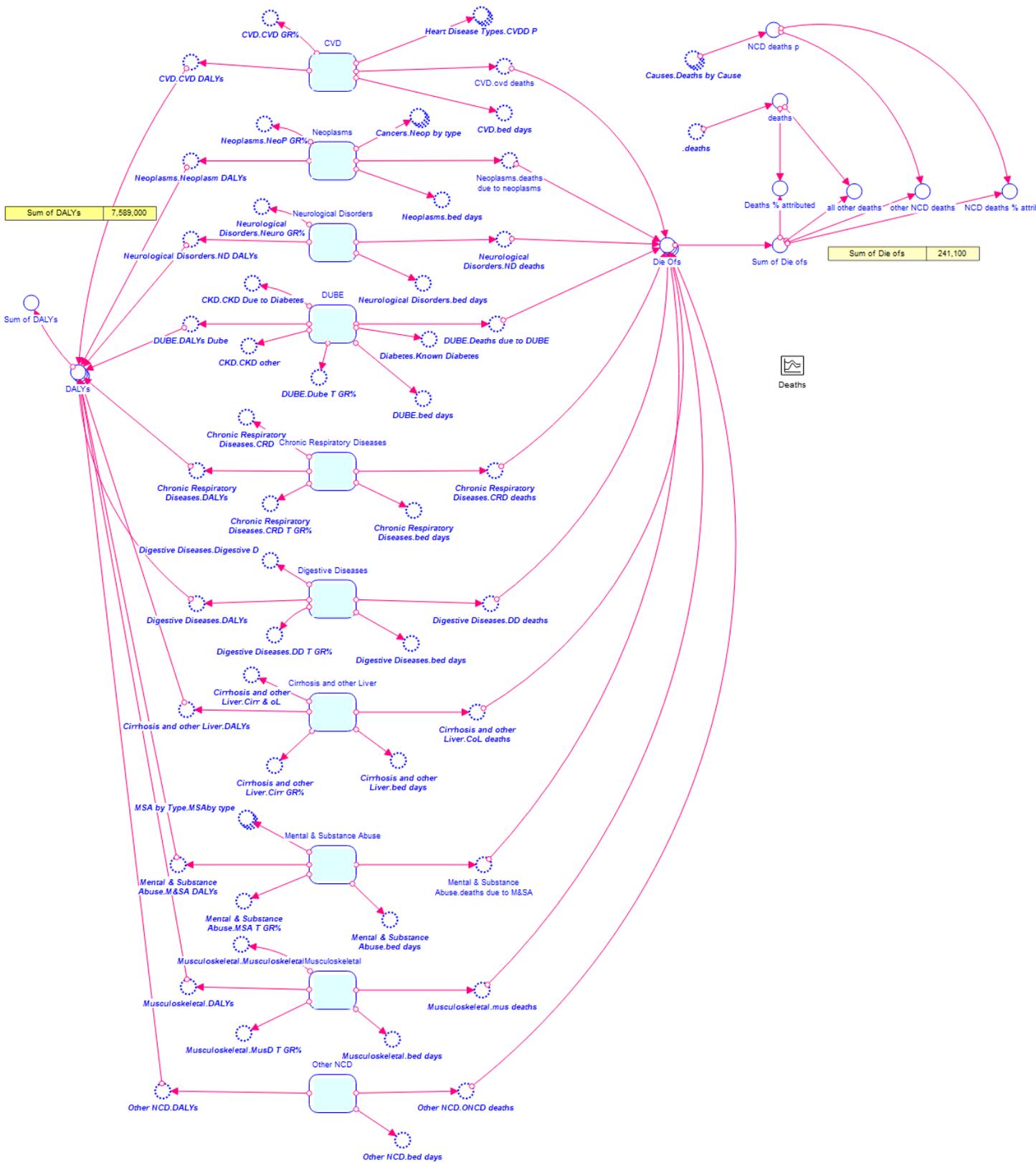


Figure 5: Module architecture for health burden calculations by major non-communicable disease groups

Types of interventions

The ACE-Prevention Study published in 2010⁴ provides the most comprehensive and widely used cost-effectiveness analysis of prevention strategies in Australia to date. This five-year study tested the cost-effectiveness of more than 150 interventions, both preventive and treatment options, to allow for a comprehensive analysis by risk factor and disease coverage. While ACE-Prevention provides a thorough examination of potential interventions, it has limited capability to assess the impact of targeting multiple interventions and combinations of risk factors, or to assess hypothetical scenarios. A dynamic simulation model with an open population and dynamic risk factor characteristics allows multiple scenarios to be tested, for a range of a risk factors, singly or in combination.

Within a modest timeframe, the Compelling Case project has developed model mechanism and structure to include a range of intervention types and demonstrate capability of system dynamics models to highlight implementation, time delay, reach and program decay issues, amongst others, over time.

In Workshop 2 (2018), the project team prepared several resources¹⁸ to support the participant group in the prioritisation and development of prevention interventions of interest for inclusion in the system dynamics model. Part of the group's objective was to prioritise interventions that could illustrate a range of possible and likely prevention intervention types, from regulation and taxation through to health promotion, screening and preventive bariatric surgery.

The project team revised the workshop participants' preferred intervention list, based on practicality and data availability. In cooperation with relevant academics and policy advisers, including Cancer Council Victoria and the Prevention Research Collaboration/Charles Perkins Centre at The University of Sydney, the project team further refined these interventions and their default assumptions and parameter ranges. The final list comprises hypothetical interventions that could be implemented nationally, through either federal or state/territory level support. Some of these simulated interventions have been designed with strongly articulated research evidence and are being promoted as future policy directions (for example, the strategy to address tobacco price dispersal), while others are more theoretically based or designed to test the comparative scope of prevention strategies in this model (for example, weight loss surgery).

Furthermore, while most interventions act in the model to reduce risk factor prevalence, a limited number act to reduce disease burden specifically. The following final interventions were initially prioritised for inclusion in the model by the core project team and the wider stakeholder group, and then defined and scoped, as detailed previously:

- Addressing price dispersal of tobacco – A regulatory intervention to influence smoking prevalence and tobacco risk factor. Incorporates standardising cigarette pack size, a minimum price of cigarettes, an accompanying national 'quit smoking' campaign, and the ability to extend tobacco excises beyond current legislative bounds.
- Social marketing of physical activity – An ongoing simulated national social marketing campaign encouraging moderate vigorous physical activity in the general population, simulating the 'ParticiPACTION' campaign data for Australia.
- Scaling up weight loss surgery – Targets high BMI risk factor prevalence. Simulates the impact of scaling up weight loss surgeries performed for adults over 38 BMI.
- Universal screening of diabetes type II for over 45s – Addresses the burden of diabetes as a risk factor for other diseases. Simulates a scaling-up of diabetes screening, from around 5,000 per year to 400,000 per year, to increase the number of known diabetes cases and those under treatment.
- Implementing a 20% alcohol volumetric tax – Addresses risky alcohol consumption prevalence by applying a hypothetical 20% additional tax on all alcoholic beverages by volume and simulating the impact on linked non-communicable diseases and overall alcohol consumption reduction.

These intervention descriptions and key assumptions are further detailed in Appendix C.

Model outputs

As this model is a representation of the health system overall, intended for use by diverse stakeholders, and as it may be a precursor to a more detailed model to be developed over time, the number of variable outputs and scenario possibilities currently generated by this model is relatively large. The list of key model outputs of relevance follows:

- Disability-adjusted life years (DALYs) – the sum of years of life lost due to premature mortality (YLL) and years lived with disability or disease (YLD)
- YLL – years lost due to premature mortality or age of death subtracted from longest possible life expectancy for a person of that age
- YLD – years lived with less than ideal health, calculated by taking the prevalence of the conditions of interest multiplied by the disability weight for that condition(s)
- Deaths due to – calculated by taking disease-related deaths multiplied by proportion of deaths related to the disease
- Risk factor prevalence – frequency of exposure of interest divided by the total Australian population
- Change in risk factor prevalence – percentage change in prevalence (by year in this model)
- Cost of illness – cost of bed day for each non-communicable disease group multiplied by average hospital bed cost per day (in 2011)
- Cost of intervention (in AU\$) and cost-benefit in DALYs – for Tobacco, Diabetes screening, and Weight loss surgery interventions - individual intervention per unit calculations within intervention model architecture
- Gross domestic product (GDP) growth – labour production component of GDP using working age proportion of the workforce, participation rate, productivity improvement factor, average compensation and productivity losses due to illness.

Importantly, model outputs are currently for demonstration purposes only and should not be used for decision-making at this stage of the model's development

While cost-benefit analysis is a key component of prioritising action to prevent chronic diseases, this proof-of-concept model has only realised this for three priority interventions – addressing tobacco price dispersal, scaling-up diabetes screening and weight loss surgery. Future extensions or expansions of this model may support further cost-benefit analysis, subject to data availability and intervention scope refinement.

Agent-based modelling and integration

Three proof-of-concept agent-based simulations were developed in partnership with ACT Health involving significant consultations and discussion with relevant program areas. Each model addresses priority policy questions on how best to minimise population level harms from tobacco and alcohol use and strategies to improve the food environment, using ACT population demographics. Each model reflected individual behaviours relevant to each risk factor, and applied the COM-B framework (**C**apability, **O**pportunity, **M**otivation influence **B**ehaviour)¹⁹ to construct and then simulate behaviour change interventions at the individual level.

1. **Food Environment Model with Cost-Benefit Analysis** – This is an agent-based simulation of healthy food policy initiatives, including the Healthy Weight Initiative, in combination with broader healthy food and drink policies in territory-owned venues, including increasing business engagement in healthy food provision/marketing and healthy sport sponsorship practices and limiting the impact of unhealthy food and drink marketing in government-controlled settings. Component behaviours described in this model include kilojoule intake and expenditure (activity levels) and weight status, work and study status and attendance at ACT-wide sporting and cultural settings or events.

Development of the food environment model as a proof-of-concept model is complete. Completion of the model documentation report and validation of the model against historical data are underway.

2. **Simulating drinking behaviour and a Minimum Pricing Intervention in the ACT population: An Agent-Based Model** – The model describes the drinking behaviour of agents in both private and social settings. Drinking was affected by addiction, withdrawal, the social network, and a personal state of engagement to try to quit or avoid starting. Different types of alcoholic beverages are described. Agents are distinguished by SEIFA quintile, which in turn impacts the price agents are willing to pay for alcohol. Simulations were conducted with 5,000 agents over a period of 20 model-years. Currently the model explores the impact of minimum pricing of alcoholic beverages on short- and long-term harms.

A further two interventions are planned to complete the alcohol use model: social marketing to decrease secondary sharing of alcohol to young people aged less than 18 years; and promotion of a responsible drinking culture. Model documentation, calibration and validation have started. The model is expected to be ready in mid-2019.

3. **Simulating Tobacco Initiation Patterns and Legislative Interventions: An Agent-Based Model of Smoking** – This agent-based model uses 10,000 agents up to age 50, where all agents are connected in a social network that models our understanding of human social networks. The smoking behaviour is affected by addiction, withdrawal, the social network, an age-based rebelliousness, and a personal state of engagement to try to quit or avoid starting. The model tests three interventions that focus on delaying or preventing the initiation of tobacco use. The interventions explore the impact of: raising the minimum age of purchasing tobacco to 21 years; increasing the compliance of tobacco retailers to minimise tobacco sales to young people; and social marketing that is focused on reducing secondary sharing of tobacco products.

The ACT model of tobacco use simulated the impact of compliance with new smoking restrictions on young peoples' smoking initiation rates. The results of these ACT-specific interventions on smoking prevalence and young people's probability to start smoking has been incorporated into the national model. This innovative approach demonstrates how integrated or 'zoomable' interactions between agent-based and system dynamics models of the same risk factor of interest, in this instance tobacco use, can be implemented.

A potential future use of this modelling work could be to integrate the tobacco and alcohol models to explore the dynamic interrelationships between alcohol and tobacco use in the ACT.

Simulation interface

The primary product of this project was an interactive digital tool that can be easily used by Prevention Centre policy partners, advocacy organisations and other researchers to demonstrate the forecasted national burden of preventable chronic disease and test the impact of a range possible prevention strategies. A web-based interface that links directly to the national system dynamics model source file is now hosted on a server, facilitating browser access to test model dynamics and results.

The interface steps through some of the project background and then simulates the burden of non-communicable disease nationally over 40 years, from 2011 to 2051, and calculates forecasted risk factor prevalence levels. It then outlines some of the hypothetical intervention strategies and allows the user to test and adjust a number of these key intervention assumptions to compare effect dynamics over time.

Importantly, as this is a proof-of-concept model, the simulation outputs and results are for demonstration purposes only and must not be used for any decision making.

Figures 6 and 7 show screenshots of the simulation and some of the detail incorporated within the model and interface.

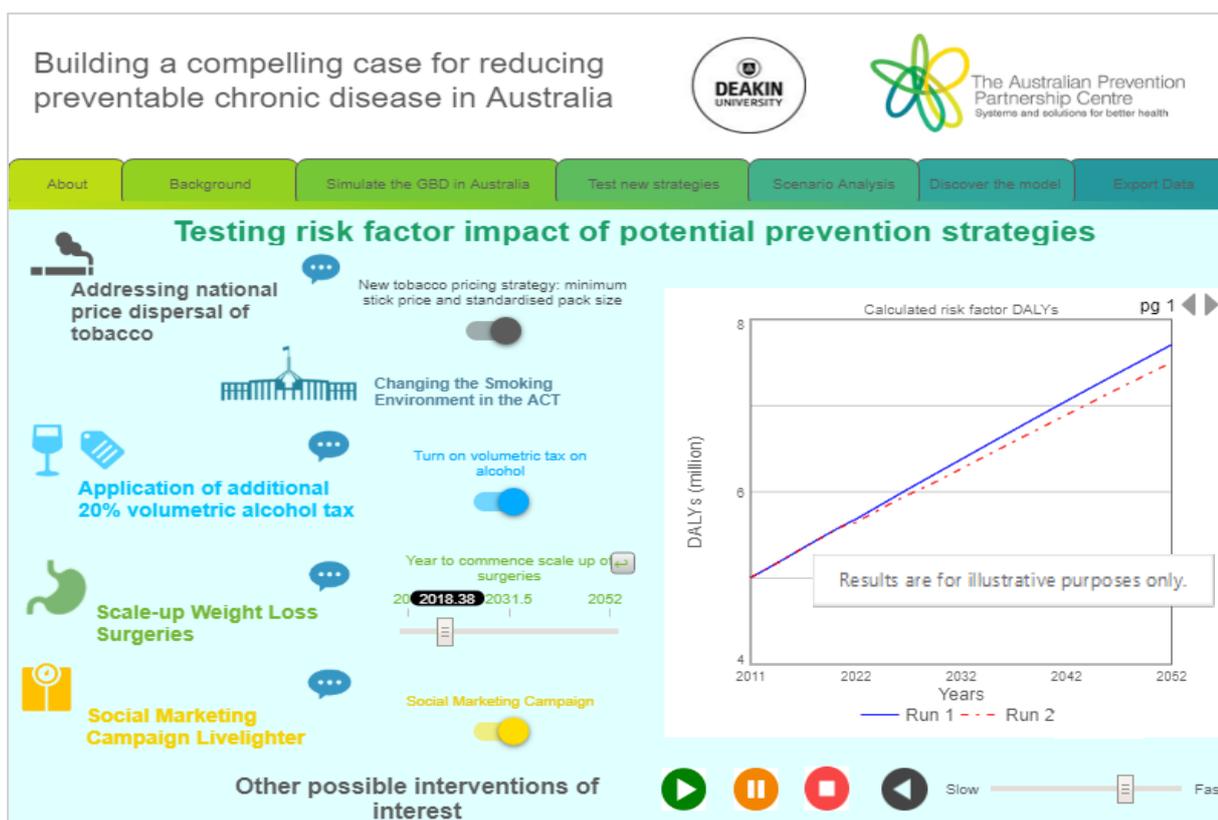


Figure 6: Simulation interface: 'Test new strategies' v314

Scenario Analysis Dashboard

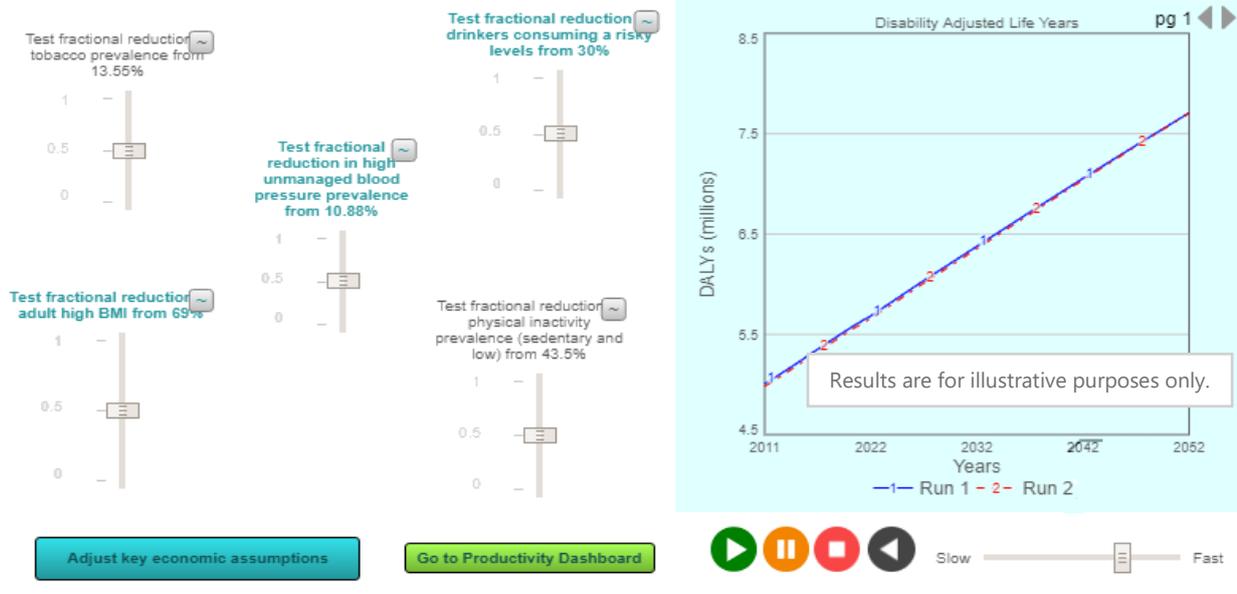


Figure 7: Simulation interface: Scenario Analysis Dashboard v314

Access to the model

The aggregate national model is digitally published for limited, password-protected access on a server as an online interactive interface of the model itself. Access is limited to key Prevention Centre partners at this stage. Further questions regarding the interface can be directed to the Associate Director of the Prevention Centre at: preventioncentre@saxinstitute.org.au

Key model insights

As a proof-of-concept national model, the intention was to develop a tool to test likely intervention scenarios and provide a broad level of comparative difference between current baseline forecasts and interventions tested. The model requires further development in order to provide decision-support for specific policy interventions. However, this national system dynamics model does provide a beneficial and important tool for demonstrating the usefulness of this modelling approach for informing the prevention and health policy debate. Some of the model's utility is in its burden forecasts over the next 40 years.

Figure 8 provides an indicative forecast by key risk factor of the DALY burden (in millions) to the year 2051 demonstrated by the national system dynamics model. In line with other forecasting tools,²⁰⁻²² the model demonstrates a consistent increase in four risk factors over time, while tobacco-related burden demonstrates a reduction influenced initially by legislated future price rises and further declines driven by declining tobacco use prevalence and a constant net migration rate.

This figure is one of many indicative forecasts and measures that the national model can produce. Other examples include: risk factor behaviour prevalence, change in prevalence over time, years of life lost due to risk factor-related disability, in addition to key economic indicators such as workplace and home-based production impacts. Forecasted health care costs by risk factor were not fully explored for this proof-of-concept model, nor full linkages between key risk factors and all 10 major chronic disease groups. Despite this, some calculations for the effect on GDP on two major disease groups, cancers and diabetes, have been produced.

Access to the simulation interface allows interested policy partners to interact with and explore the outcomes of interest produced by the model to date.

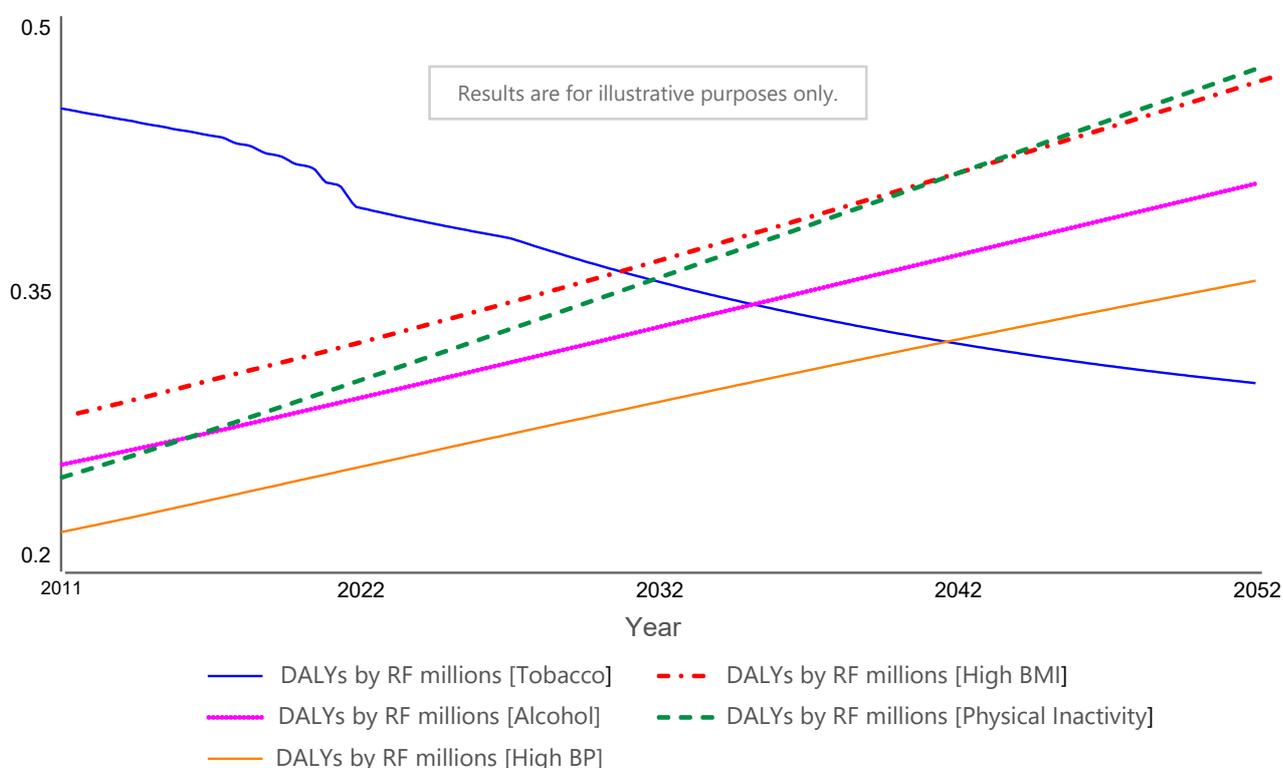


Figure 8: Forecasted model DALY burden by key risk factor v314

Priority interventions tested

After the core national system dynamics model was built, the project team and project stakeholders discussed a proposed range of prevention intervention strategies that could be implemented on a national basis (either nationally implemented by all state governments or implemented through the Australian Government).

While the project aimed to test a range of strategies by type and was not restricted by those considered the best buys in specific chronic disease-related research, the selection process considered interventions that:

- Primarily impacted on a risk factor, not disease
- Were of current interest to researchers and advocates
- Could potentially be replicated across other risk factors of interest, for example, excise increases or screening programs
- Had scope which could be clearly defined and data readily available
- Met pragmatic considerations including limitations of time, resources and computational size.

Most interventions selected in this model reflect either a scale-up of currently piloted or trialled strategies, or a replication of interventions applied in overseas jurisdictions. Only one, the minimum pricing and standard packaging of tobacco, represents a truly novel intervention, which is reflective of the currently unique tobacco retail environment in Australia. The universal screening for type 2 diabetes reflects prevention of a major disease group, as opposed to a key risk factor. However, this intervention represents the diversity of a likely suite of prevention strategies in use by governments. The full list of interventions modelled is found in Appendix C.

Access to costing data and time influenced the ability to fully cost all interventions included in the model. Only three interventions have been costed sufficiently to provide the capability to demonstrate cost-benefit data: type 2 diabetes screening, weight loss surgeries and tobacco price dispersal standardisation legislation.

As a proof-of-concept model, this simulation is limited in the extent to which it can demonstrate effect for real-world, or at least policy-realistic scenarios.

It is anticipated future versions of this national model can build on these interventions, refine or contest these assumptions and build more real world policy scenarios into the simulation as required. Given the dynamic policy environment of the Commonwealth and state governments, it is possible interventions in the model could either be under consideration or not. The national model does not at this stage reflect the chronic disease policy inclusions of any specific state, territory or Commonwealth jurisdiction.**

Each intervention calculates a risk factor behaviour prevalence change (or in the case of diabetes type 2 screening, disease prevalence change) and links these to YLL and YLD calculations for each respective risk factor. DALY reductions can then be calculated and estimated over time. However, risk factor prevalence DALYs are not linked to their related diseases nor disease modified DALYs; with the only exception being the diabetes screening intervention and its impact on diabetes-related DALYs. As a proof-of-concept model, the ability to explore all these interactions and disease progressions was demonstrated but could not be fully realised within the timeframe of this project.

The example provided below demonstrates just one of the many scenario-analyses this model can produce. It should be noted that this simulation can generate numerous possible scenarios, using single interventions, or

** However, the three risk-factor agent-based models were specifically designed around the ACT Government's priorities and programs.

combinations of interventions. The comparative reductions in DALYs in this example have limited policy usage and should not be referred for decision support. The comparisons do, however, highlight the model's capabilities for potential analysis.

Figure 9 shows the impact over time of selected interventions on calculated overall ('modified') DALYs. Run 1 represents the forecasted baseline or anticipated growth in DALYs over the next 40 years, assuming current default measures and strategies remain in place. Each of the other four runs represents hypothetical interventions, each specifically targeting one individual risk factor prevalence (and/or initiation rates or quit rates) which impact the respective risk factor DALY calculations over time. The summaries of these risk factor interventions are provided below and are further described, including default assumptions and key parameters in Appendix C.

Around 10 years of implementation of any of these prevention interventions is required before any reduction in the growth of DALYs can be seen. At around year 20 (or 2031), a reduction of around 20,000 DALYs, or 0.3% of attributable DALYs in that year, can be achieved by any one hypothetical intervention. Not until around year 40 (or 2051) can around 100,000 DALYs be averted by any one of these interventions, or 1.3% of attributable DALYs, assuming these interventions are being consistently implemented over this period.

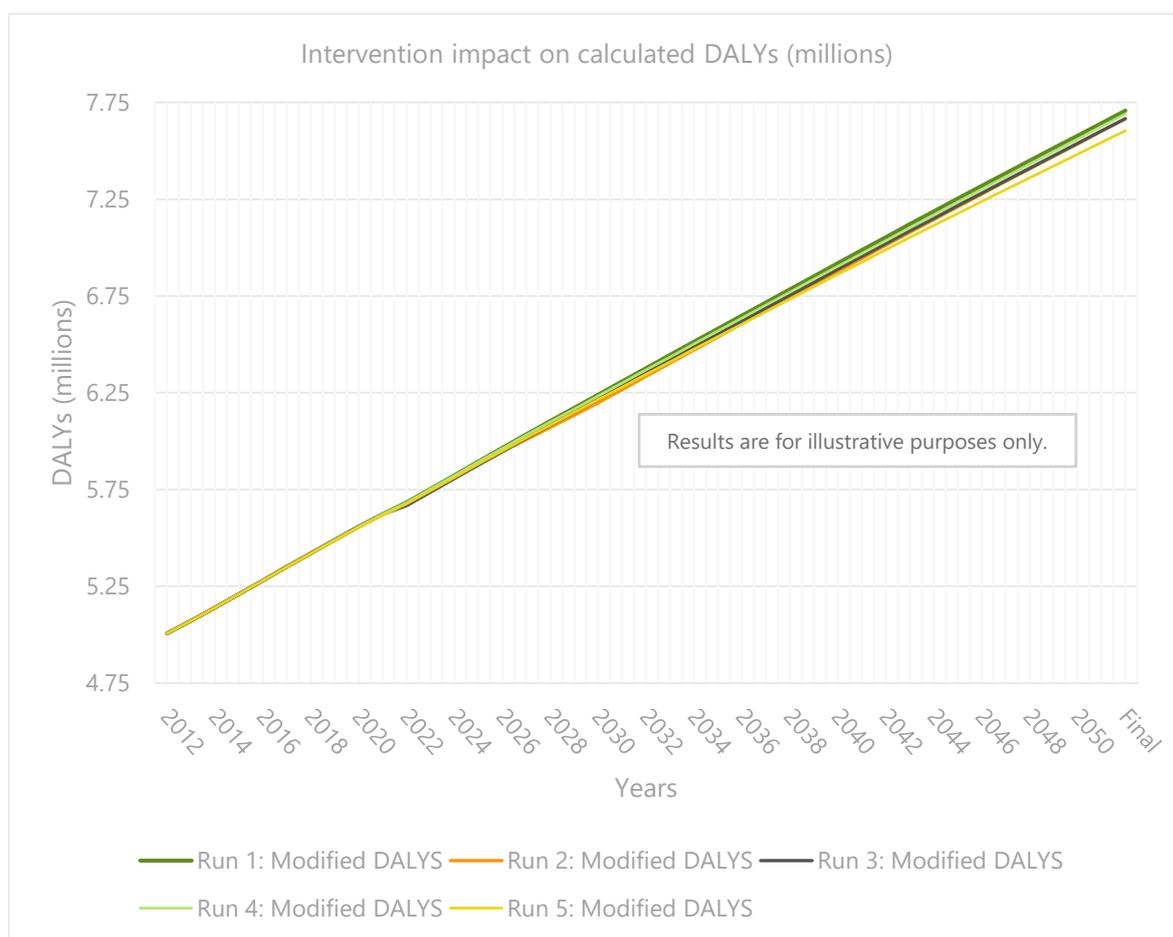


Figure 9: Hypothetical risk factor reduction interventions and indicative outcomes on DALYs – model version 314

Run definitions for Figure 9

RUN 1 – Baseline Run. Assumes business as usual regarding current programs, treatment, and prevention services. In this baseline run, the model produces non-communicable disease-related DALYs for Australia over time. The baseline shows calculated DALYs increasing from around 5,007,000 in 2011 up to around 7,707,000 40 years hence.

RUN 2 – Tobacco Risk Factor. This intervention simulates several mechanisms that have the potential to influence smoking prevalence (tobacco risk factor) and is referred to as an intervention to 'address national price dispersal of tobacco. The aim of a wholesale floor price is to reduce consumption of cigarettes and roll-your-own (RYO) tobacco by the most price sensitive smokers and reduce the variability of price amongst brands of cigarettes by introducing the standardisation of packs of cigarettes to 20s and 25s, and RYO pouches to 30g only. A minimum wholesale price per cigarette (\$1) and \$1 per gram of RYO tobacco is proposed to commence in 2021, immediately following the final excise rates increase. The estimated one-off increase in tobacco prices as a result of minimum stick price implementation is assumed to be 10%. Alongside this price floor, the standardising of cigarette pack sizes is modelled, which commences in 2025, together with a national QUIT campaign.

RUN 3 – Alcohol Risk Factor. Application of an additional 20% volumetric alcohol tax. This is a simplified simulation of an additional volumetric alcohol tax. This intervention assumes the current mix of alcohol beverage excises/taxes are present. This new tax commences in 2018, takes three years to be fully implemented and impacts directly on both alcohol quit rates and overall consumption levels, and therefore chronic disease reduction (after 20 years). Consumption reduction is an S-shaped estimate, represented graphically, that reduces consumption by 20% at a tax level of 20%. This intervention simulates an across the board linear impact on all non-communicable disease (not disease specific) of 10% reduction for an overall alcohol consumption reduction of 20% after 20 years.

RUN 4 – High BMI Risk Factor. Scaling up weight loss surgery. This scale up scenario simulates the scale up of the four main types of weight loss surgeries performed in Australia – sleeve gastrectomy, gastric banding, R-Y gastric bypass and S-A gastric bypass, up to the maximum level of 40,000 primary procedures per year for those who pre-qualify with a minimum BMI of 38, from a current baseline of around 22,000 pa. The effect of this surgery impacts high BMI prevalence, and its impact on disease specific DALYs. A cost-benefit of 'DALY's avoided' due to weight loss surgery is demonstrated here.

RUN 5 – Physical Inactivity Risk Factor. National social marketing Livelighter campaign. This intervention simulates a theoretical application of a social marketing model, known as the Hierarchy of Effects to a campaign to influence high rates of physical inactivity in the general population. It simulates proportions of the population who are aware of the campaign, those who understand its relevance to them, who develop a new attitude (because of the campaign), intend to act, undertake initial behaviour change, and the length of time this proportion remain engaged with the behaviour change. Physical activity experts provided advice on the use of social marketing physical inactivity evaluations of the WA Livelighter campaign and long-term data from the Canadian ParticipACTION campaign to inform this intervention. This campaign currently assumes those undertaking a change in physical activity as a result of this ongoing campaign will affect the current proportions of those undertaking either high, medium, low or sedentary activity levels.

What we learned

The current proof-of-concept national model of chronic disease burden supports multiple demonstration interventions. However, for the model to be fully realised as a policy relevant and practical tool, the full linkages between risks, diseases and co-morbidities should be prioritised.

Due to time constraints, it was not possible to demonstrate completely all levels of interactions between risk factor behaviour and disease progression and burden in this proof-of-concept model. Although the model demonstrates this capability for one disease group, diabetes, it remains a key challenge for refining the model in the future.

Similarly, the integration of outcomes of scenarios simulated in the ACT agent-based risk-factor models was achieved to a limited extent only, to provide an exemplar for future model integration. Using further analysis conducted with these ABMs, it would be possible to identify optimal behavioural parameters of relevance and benefit to the national system dynamics simulation.

Another area for progress in the model is to capture co-risk factor prevalence and their impact on disease burden. The current model structure for six individual risk factor behaviours would allow further development of co-risk factor calculations, where source data exists. This next stage of model development is arguably essential for building a more refined forecasting tool, as co-risk factors and co-morbidities are now recognised as important for understanding the growing non-communicable disease burden.

While this current model accessed individual disease burden calculations for only the top 10 diseases, there is an argument to be made for extending this further to, for example, the top 20 diseases by burden. While changes in calculation to the overall burden would not be affected, extending the risk factor-related individual disease number would allow for improvements in calculations and communication of possible risk factor changes and a more representative impact on disease burden.

Similarly, a thorough compilation and calculation of attributable healthcare costs by disease and risk factor remains a priority for future model extension work.

Further development of the model would also involve a more comprehensive representation of health economic outcomes. Cost offsets represent the costs of treating and managing disease that are saved in scenarios of risk factor prevalence reduction. When combined with the cost of interventions, incremental cost effectiveness ratios can be calculated to allow relative cost-effectiveness between interventions to be compared. Further extensions to calculate net monetary benefit which encapsulates production impacts of workforce productivity, home-based production and leisure-based production would assist in establishing the overall economic value of risk factor reduction scenarios or specific prevention interventions. This collection of model outcomes would provide a comprehensive set of cost-effectiveness analyses to inform investment decisions around prevention initiatives.

Additionally, an important area or consideration in further model refinement and development are sub-population analyses. Several stakeholders raised this as an important consideration in the utility of a preventable chronic disease model. In particular, being able to identify intervention implications not only for the general population but also Aboriginal and Torres Strait Islander people and the population in the lowest two SEIFA quintiles was identified as being a practical addition. To achieve this, further population arrays and intervention effect sizes with respect to these sub-populations would have to be researched and then reworked into the model structure and interface.

All system dynamics models are aggregations or approximations of the real world and rely on estimations of probability of a factor influencing another, an estimate of effect size or a distribution for a pattern of implementation. This demonstration model utilised several assumptions around intervention implementation that will require refinement so as to satisfy its use as a 'policy-ready' tool for real-world use.

Improving the design and effectiveness of the online simulation interface through further feedback and consultative approaches is also an area where resources could be allocated.

Conclusion and next steps

As confirmed by the systematic reviews conducted for this project, the last time the health and economic burden of multiple risk factors was estimated was by Deakin Health Economics for VicHealth in 2009. The Compelling Case project presents an opportunity to update these estimates using modern dynamic simulation modelling techniques to more accurately represent the dynamic nature of the population, modifiable risk factors and disability or disease progression over time.

This system dynamics model represents a significant advancement in conceptualisation and scope with respect to previous single risk factor population and burden models. The project has enabled the Prevention Centre to establish that the system dynamics of preventable chronic disease burden can be modelled. Prior to this model only individual risk factors and several outcomes of interest had been successfully modelled using system dynamic techniques in the health policy sphere in Australia.

The Prevention Centre has refunded the project until November 2020. The second phase of project aims to:

- Develop the proof-of-concept national systems dynamics model into a customised, validated, robust decision support tool to inform national strategies for lifestyle-related chronic disease prevention in Australia
- Engage key decision makers in the customisation of the tool and, where possible, build embedded capacity within health departments to use and maintain the tool and generate insights useful for informing policy and planning over the longer term
- Integrate and exercise the agent-based models developed during the first phase (particularly the tobacco and alcohol models) to generate inputs for the national model and derive insights for policy, planning, advocacy, communications and publication in the scientific literature.

This project will demonstrate to our policy partners that they can use the national model to support their decision making. It will also show that the model can be updated as new data becomes available, making it a long-term decision support asset for best buys in chronic disease prevention and burden reduction.

In addition, the national model will be able to be customised and made applicable to different population levels, such as at state and territory level, in the future.

Acronyms

ABMs	agent-based models
BMI	body mass index
DALYs	disability-adjusted life years
GDP	gross domestic product
RYO	roll your own tobacco (loose tobacco)
SD	system dynamics
SEIFA	Socio-Economic Indexes for Areas
YLLs	years of life lost
YLDs	years of life lived with disability

Glossary

Term	Definition
Ageing chain	A stock and flow structure used in system dynamics to represent the ageing of the population.
Agent	Agents in agent-based modelling may represent an individual object. Agents can represent almost any individual object, for example, people, vehicles, projects, products or countries. ²³
Agent based modelling	<p>A computer modelling method that simulates the actions and interactions of agents (i.e. individuals or collective entities such as organisations or groups) with a view to assessing their effects on the system as a whole²⁴.</p> <p>This method is good at capturing heterogeneity in risk and in impacts of interventions and can capture social network influences.</p>
Calibration	A process for tuning some parameters of the model so that the model's behaviour in particular conditions matches a known (historical) pattern.

Term	Definition
Dynamic simulation modelling	Dynamic simulation modelling is a systems science method that can be used to explore and understand problems that appear in the real-world using computer simulations. ^{23, 25} Methods include system dynamics modelling, agent-based modelling, discrete event simulation methods.
Flows	Flows are also components used in system dynamics modelling. They are the rates at which the stocks (or system states) change. Flows are typically measurements of quantities in a given time period such as clients per month, dollars per year or incidence of disease during a defined period ²⁵ .
Initialisation	The set of parameter values used at the start of the simulation.
Model structure	The way the elements of a system are represented in the model or interrelated; the building blocks of the model including state-charts, stock and flow diagrams and process diagrams.
Parameter	Parameters are used for quantifying characteristics of the modelled objects and relationships between them. A parameter is normally a constant in a single simulation and is changed only when the model behaviour needs to be adjusted (https://help.anylogic.com/index.jsp).
State	Represents the "state" of the agent e.g. the agent is either in a pregnant state or not pregnant state. States are mutually exclusive and agents transition between states according to the state-chart rule. ²³
Stocks	Stocks are components used in system dynamics modelling. They are accumulations and characterise the system state. Stocks are usually expressed in quantities such as people, inventory levels, money, or knowledge. ²⁴
System dynamics	System dynamics is a method for understanding how systems change. It models the relationships between elements in a system and how these relationships influence the behaviour of the system over time ^{1, 25-27} . Important elements of system dynamic models include feedback loops (the circular causality in the system), stocks and flows.

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Appendix A – Stakeholder workshop participants, intervention interview discussants and core project team members

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Linda Cobiac, **University of Melbourne**

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Jennifer Taleski, **ACT Health**

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Emma Slaytor, Prevention Centre

Andrew Wilson, Prevention Centre/University of Sydney

Sonia Wutzke, Prevention Centre

Appendix B – Steps in the Compelling Case for Prevention development process (system dynamics and agent-based models)

- Develop test and refine an overall framework (iterative)
- Plan and refine the overall scope and level of detail with stakeholders (iterative)
- Plan and refine the types and specific interventions and outcomes with stakeholders (iterative)
- Build an open population (births, deaths, migration) with people's life course
- Add people with risks, diseases and linked diseases, deaths, with fatal burden of disease YLL
- Add people with disease onset, progression, duration, disability for non-fatal burden YLD
- Add relevant activities of daily living (education, working, leisure activities, caring)
- Add other relevant objects and actors (e.g. hospitals, technology, workforce)
- Handle interactions among risks, diseases, interventions, and outcomes
- Add health services use, control mechanisms and other processes of interest at the aggregate level
- Add special populations of interest and social networks (e.g. families, households, settings based)
- Add relevant environmental context including relevant aspects of ecological (natural and built environments), social (political economic, social networks and cultural), and technical (e.g. disadvantage, food, urban land use, infrastructures). This can be considered the stage on which the narratives play out
- Refine display and reporting of outcomes of interest from multiple perspectives
- Add economic indicators
- Add other indicators of value at multiple levels
- For individual based models (agent based and process centric) add agent concerns, processes, agent to agent interactions and agent environment interactions:
 - Growth and development of capabilities
 - Healthy habits and risky behaviours
 - Stress, distress and diagnosable disorder symptoms
 - Disease progression and recovery
 - Health seeking behaviours
 - Diagnosis (including testing and interpretation) and treatment
 - Assessing referring monitoring planning and ongoing management
 - Formal and informal care and production processes.

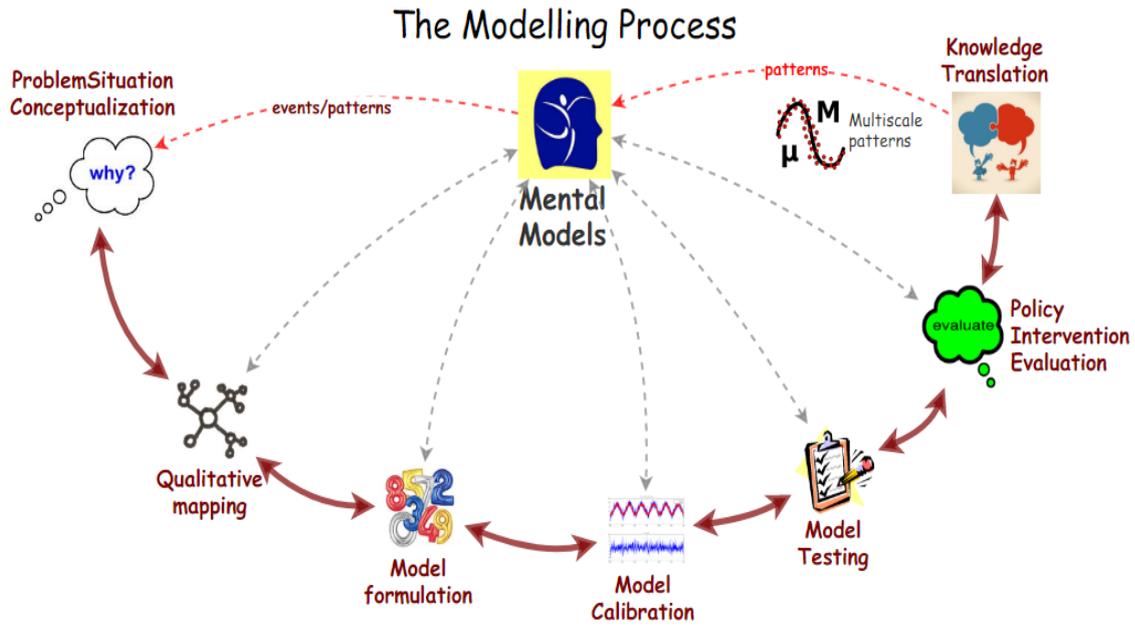


Figure 1: Schematic of the overall modelling process

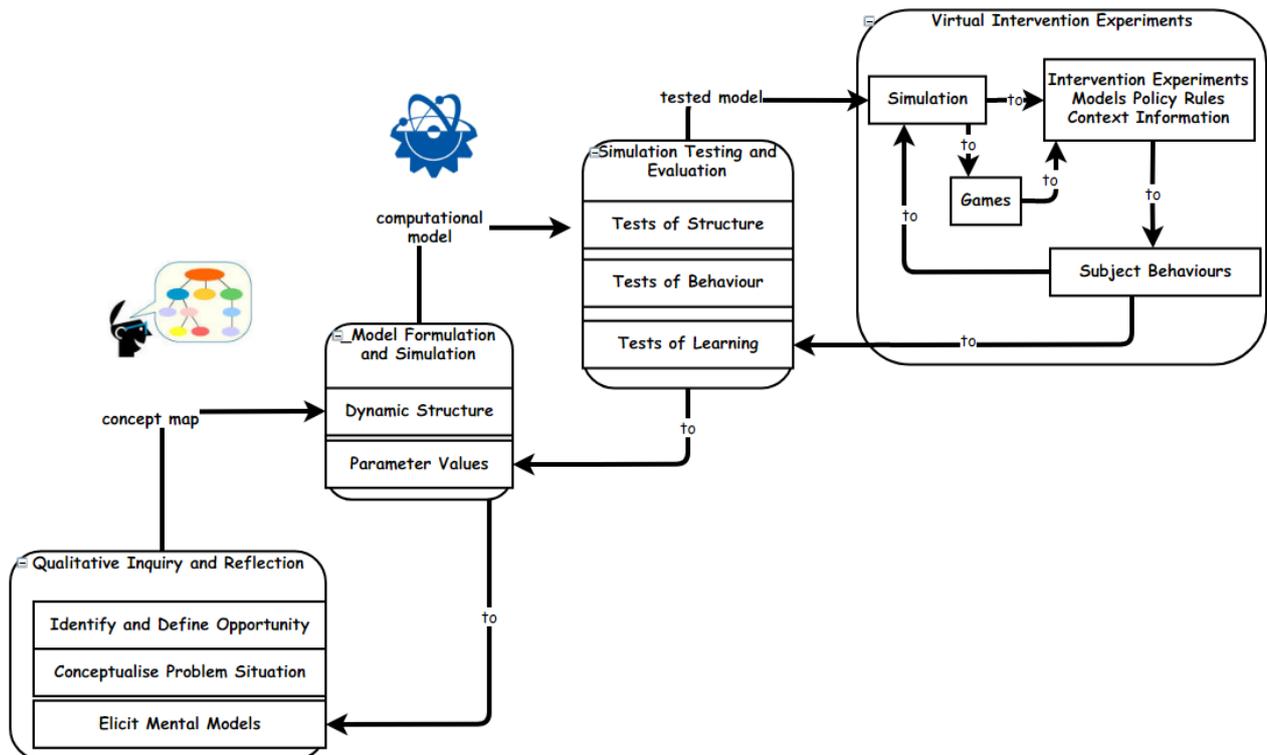


Figure 10: Further details of the modelling process

Appendix C – Description of modelled interventions

Risk factor related interventions

Risk factor	Intervention type	Description and key parameters	Cost-benefit analysis
Tobacco use/Smoking	Regulatory/ environmental and social marketing	<p>Addressing price dispersal in the Australian tobacco market: tobacco minimum pricing and standardised pack size together with a ‘Quitline-type’ mass media campaign</p> <p>This national tobacco price policy intervention builds on the successes of previous tobacco price policy changes around excise and plain packaging. With these policies now embedded within the preventive health and legislative systems, new tobacco policy changes are now being advocated that address the wide price dispersion of tobacco products in the Australian market. This ‘reducing price dispersion’ proposal has been developed with Cancer Council Victoria to inform their cancer prevention advocacy agenda.</p> <p>The aim of a wholesale floor price is to reduce volumetric consumption of cigarettes and RYO tobacco and increase the base quit rate of the most price sensitive smokers. The second component is to reduce the variability of price amongst brands of cigarettes through the standardisation of pack availability of cigarettes to 20s and 25s (from the current wide product range of 18s, 20s, 25s, 30s, 40s and 50s) and RYO pouches to 30g only.</p> <p>In this simulation, a legislative-enacted minimum wholesale price per cigarette of \$1 and \$1 per-gram of RYO tobacco is proposed to commence in 2021 nationally, immediately following the final excise rates increase. The proposal for standardising of cigarette pack sizes nationally to 20s and 25s, and tobacco pouches to 30g is proposed to commence in 2025 in this model and take two years to achieve full implementation.</p>	Yes

Risk factor	Intervention type	Description and key parameters	Cost-benefit analysis
		<p>The effect of both standardised pack size and a price floor is seen in this model on the change in smoking prevalence quit rates, or more specifically cessation attempt rates, differentiated by age group. Additionally, the effect of price on 13–17-year-olds and 18–29-year-olds significantly impacts smoking initiation rates and on ‘the willingness to share cigarettes’ in this simulation. Data to support this effect was included from the ACT agent-based model of smoking behaviour to demonstrate interactivity between ABM and SD models.</p> <p>These changes in quit rates and initiation rates modify both the overall consumption of tobacco per week and the overall tobacco prevalence. These both influence the level of change in tobacco harms, from which changes in tobacco-related DALYs and other economic indicators can be calculated.</p> <p>Both these intervention components are supported by a national quit smoking mass media campaign in this model. The social marketing campaign will be able to be switched on or off in this simulation interface to enable users to assess the impact of minimum price and pack size policies changes alone or in combination. This model will simulate a four-year, \$40 million per year, achieving a total of 4,000 television Target Audience Rating Points per year. It will target 25–49-year-olds over 5 x 6–8-week campaigns per year, plus 30% additional supportive advertising via radio, outdoor, online and social media. All campaign messages subject to exploratory research, concept development and pre-testing and ongoing campaign monitoring and evaluation.</p>	
High BMI	Population-level clinical treatment/ Secondary prevention	<p>Weight loss surgery scale up</p> <p>This scale up scenario simulates the scale up of the four main types of weight loss surgeries performed in Australia – sleeve gastrectomy, gastric banding, R-Y gastric bypass and S-A gastric bypass – up to the maximum level of 40,000 primary procedures per year for those who pre-qualify with a minimum</p>	Yes

Risk factor	Intervention type	Description and key parameters	Cost-benefit analysis
		<p>BMI of 38, from a current baseline of around 22,000 p.a. The effect of this surgery impacts high BMI prevalence, and its impact on disease specific DALY relating to cardiovascular disease, type 2 diabetes and chronic kidney disease. A cost-benefit of 'DALY's avoided' due to weight loss surgery is demonstrated here.</p> <p>The scale up of surgeries commences in the year 2020, and the initial BMI threshold is set at 38. An index of learning is applied in the model that impacts operations costs (surgeries cost 90% for each doubling of procedures performed), suitable candidates, candidates requiring revision surgery and candidate BMI threshold.</p> <p>The effect of weight loss surgery in this model is on a reduction in the proportion of YLDs attributed to CVD, Diabetes and CKD.</p>	
Alcohol	Tax policy/ Structural	<p>Implementing an additional 20% alcohol tax</p> <p>This is a simplified model structure that simulates the effect of an additional 20% tax commencing in mid-2018, taking three years to be fully implemented. Although the tax has an immediate effect on quit rates and consumption reduction in this model, and therefore the number of risk drinking occasions, the effect on chronic disease reduction is assumed to require 20 years to be seen in this model.</p>	No
Physical inactivity	Social marketing	<p>Liveliighter type national marketing campaign</p> <p>This is a national physical activity social marketing campaign that uses 30-year evaluation data from the Canadian ParticipACTION campaign (Craig, CL. An evaluation of the My ParticipACTION Campaign to Increase self-efficacy for being more physically active. J Health Commun. 2015;20(9):995-1003) to simulate an ongoing campaign in Australia targeting an increase in physical activity in adults. It uses a theoretical model as a basis for the proximal and intermediate effects of modelled behaviour change (Bauman A. et al. Testing a hierarchy-of-effects model: pathways from awareness to outcomes in the VERB campaign 2002–2003. Am J</p>	Not linked

Risk factor	Intervention type	Description and key parameters	Cost-benefit analysis
		<p>Prev Med. 2008;34(6 Suppl): S249–256 and Kite J et al. A systematic search and review of adult-targeted overweight and obesity prevention mass media campaigns and their evaluation: 2000–2017. J Health Commun.2018; 23(2):207–232.) The campaign assumes a ~4,000 TARP per month campaign of full-intensity three-month duration, repeated every two years and a decay period of two years, with a loss of interest leakage rate (a residual campaign memory of 20%). With an estimated 80% reach, a proportion of the target population become aware of the campaign, then understand the campaign is relevant to them, then develop the self-confidence in their ability to change behaviour, intend to act (change behaviour) and subsequently initiate moderate-vigorous physical activity. This intervention is limited in its assumptions of long-term behavioural effects (distal effects), therefore the over-stating of those continuously undertaking MVPA may be evident in this simulation. Source data: Australian Institute of Health and Welfare. Physical activity. Retrieved 5 November 2018, from www.aihw.gov.au/reports-statistics/behaviours-risk-factors/physical-activity/overview</p>	

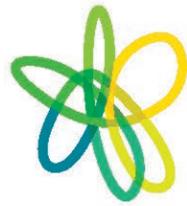
Addressing disease burden intervention (as a risk factor for other diseases)

Disease	Intervention type	Description	Cost-benefit analysis
Type 2 diabetes	Secondary prevention (Screening)	<p>Universal screening for type 2 diabetes in over 45s</p> <p>This hypothetical intervention demonstrates the impact of conducting universal diabetes screening across the national population aged 45 years and over. Current, BAU estimates of annual screening are 5,000 pa in this defined age group; the intervention will demonstrate the impact of screening 400,000 pa. This screening process is defined as a two-step process that includes an AUSDRISK (diabetes risk assessment) followed by a fasting blood glucose test for those who score 12 or more, conducted at a community pharmacy or primary health clinic. Although referral to further primary health care would be provided for those who recorded an abnormal blood glucose test result, only the direct Medicare costs of the screening intervention are included in this model.</p> <p>The majority of those who are positively diagnosed with diabetes mellitus in this model are then assumed to have 'managed uncomplicated diabetes', while a proportion remain 'unmanaged'. Over time a proportion of the managed cases these will develop complicated diabetes and die from these complications in the model and drives a rise in YLDs and YLLs. However, those who manage their uncomplicated diabetes are assumed to have an increased life expectancy (over those with undiagnosed diabetes) which reduces the overall proportion of YLDs in the model attributed to population level diabetes prevalence.</p> <p>This intervention demonstrates the impacts of screening on the overall capacity of the healthcare system to manage the additional known cases of diabetes, the known 'swamping effect'. While DALYs can be avoided by increasing the uncomplicated managed cases of diabetes, it is clear additional resources (or 'management capacity') are required to reduce the death rate of those whose progression to diabetes with complications is increased as treatment capacity cannot be increased.</p>	Yes

Other interventions of interest

These interventions are modelled with only basic assumptions and calibration but are provided to demonstrate model capability and potential for further refinement and development.

Risk factor	Intervention type	Description	Cost-benefit analysis
High blood pressure	Clinical/ Secondary prevention	Idealised blood pressure management scenario This intervention slider allows the user to increase the proportion of those who manage their high blood pressure, to 5% per year. Implementation or program mechanism is not modelled.	No
Poor diet (excess kilojoule intake)	Population -level clinical primary prevention	'Healthy eating' program. This is an idealised intervention to demonstrate the effect of a population-level 'Health eating' type kilojoule reduction program that directly affects the overall energy balance. The simulation assumes that the target kilojoule reduction in the whole population is 10%, that this can be achieved in 10 years, that the program commences in 2020, and that there is an underlying kilojoule increase of 0.25% pa in the population.	No



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