“Turning mirrors into windows”: A study of participatory dynamic simulation modelling to inform health policy decisions

Louise Freebairn

Follow this and additional works at: https://researchonline.nd.edu.au/theses

Part of the Medicine and Health Sciences Commons
Chapter 3: Research methods

Section 3.1 in this chapter presents the published research protocol. This paper also explored the challenges associated with achieving evidence-based health policy making, and how system science applications to knowledge mobilisation, such as participatory DSM, have potential to overcome these challenges. Important gaps in knowledge are identified, including firstly, whether it is feasible to use a participatory approach to dynamic simulation modelling as a method for evidence synthesis and decision support in “real-world” public health settings. Secondly, what are the perceived value and efficacy of participatory simulation modelling methods from the perspective of end users.

Section 3.2 describes how the research methods evolved following publication of the research protocol. Section 3.3 describes my role in the primary DIP case study and the two supplementary case studies to examine the participatory DSM approach. Also included in Section 3.3 is a summary of the research questions, and their relationship to the study objectives, data sources, and the other chapters in thesis. Section 3.4 provides the relevant information about the ethics approvals for this research.

3.1 Paper 1: Simulation modelling as a tool for knowledge mobilisation in health policy settings: a case study protocol

Simulation modelling as a tool for knowledge mobilisation in health policy settings: a case study protocol

L. Freebairn 1,2,3*, J. Atkinson 2, P. Kelly 1,2,4, G. McDonnell 2,5 and L. Rychetnik 2,3

Abstract

Background: Evidence-informed decision-making is essential to ensure that health programs and services are effective and offer value for money; however, barriers to the use of evidence persist. Emerging systems science approaches and advances in technology are providing new methods and tools to facilitate evidence-based decision-making. Simulation modelling offers a unique tool for synthesising and leveraging existing evidence, data and expert local knowledge to examine, in a robust, low risk and low cost way, the likely impact of alternative policy and service provision scenarios. This case study will evaluate participatory simulation modelling to inform the prevention and management of gestational diabetes mellitus (GDM). The risks associated with GDM are well recognised; however, debate remains regarding diagnostic thresholds and whether screening and treatment to reduce maternal glucose levels reduce the associated risks. A diagnosis of GDM may provide a lever to multidisciplinary lifestyle modification interventions. This research will apply and evaluate a simulation modelling approach to understand the complex interrelation of factors that drive GDM rates, test options for screening and interventions, and optimise the use of evidence to inform policy and program decision-making.

Methods/Design: The study design will use mixed methods to achieve the objectives. Policy, clinical practice and research experts will work collaboratively to develop, test and validate a simulation model of GDM in the Australian Capital Territory (ACT). The model will be applied to support evidence-informed policy dialogues with diverse stakeholders for the management of GDM in the ACT. Qualitative methods will be used to evaluate simulation modelling as an evidence synthesis tool to support evidence-based decision-making. Interviews and analysis of workshop recordings will focus on the participants’ engagement in the modelling process; perceived value of the participatory process, perceived commitment, influence and confidence of stakeholders in implementing policy and program decisions identified in the modelling process; and the impact of the process in terms of policy and program change.

Discussion: The study will generate empirical evidence on the feasibility and potential value of simulation modelling to support knowledge mobilisation and consensus building in health settings.

Keywords: Health systems, Participatory simulation modelling, Gestational diabetes mellitus, Group model building, Evaluation, Knowledge mobilisation

* Correspondence: louise.freebairn@act.gov.au
1ACT Health, GPO Box 825, Canberra ACT 2601, Australia
2The Australian Prevention Partnership Centre, Sax Institute, PO Box K617, Haymarket NSW 1240 Sydney, Australia
Full list of author information is available at the end of the article

© 2016 The Author(s). Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.
Background

Health systems are under continual pressure to provide accessible and effective health services within limited slow growing or reducing budgets. In this context, decisions regarding the best investment of health funds need to be well informed, reviewed regularly and aimed at achieving the greatest health gain for the investment.

The divide between research and health system actions has been frequently recognised [1–3]. Knowledge derived from research and experience will be of little benefit unless it is utilised and its success monitored [1]. There is a need to bridge the gap between the increasingly sophisticated research on using evidence and practitioner knowledge to inform practice and policy and the pragmatic nature of agency decision-making for strategies and actions [2]. Advances in technology have led to increased adoption of tools and methods aimed at integrating diverse evidence sources to inform decision-making [4, 5]. However, rigorous assessment of the value and utility of these methods and tools is required prior to them being more generally adopted for evidence-based decision support. The application of systems science and simulation modelling to the decision-making process is an innovative area with great potential value for those responsible for allocating scarce resources [6].

What are the challenges of evidence-informed policymaking?

Evidence-informed policy decisions are essential to ensure that health intervention programs and service plans are likely to be effective and offer value for money. However, barriers to the use of evidence to inform decision-making remain [7] and the use of published research to inform policy development is often limited [8]. Descriptive evidence and analytical studies are used to describe issues and inform priorities; however, evidence on the implementation and impact of interventions is less commonly used to inform program planning decisions and strategic actions [7]. In some cases, program decision-making can be driven by “informed guesswork, expert hunches, political and other imperatives” [9].

To address this, evidence provided to policymakers needs to be in a form that is useful to them [10–12]. Policymakers require synthesised and localised data that contrasts and prioritises policy options, demonstrates effectiveness of interventions, demonstrates the need for a policy response, demonstrates cost effectiveness of actions, reflects the level of public support for a particular issue and personalises the problem [12, 13]. In addition, policy and program decision-making processes are rarely linear. They are frequently iterative processes and are influenced by a range of inputs such as political environment, budget constraints, resources, values, available expertise and ethics [7, 12, 14, 15].

Even when research evidence is considered, as in public health policy development for the prevention of chronic disease [2], this evidence often points to a large range of risk factors that contribute to the problem, including broader social determinants of health. Our lack of understanding about how these risk factors interact, and which are the most important, have resulted in the development of more comprehensive, cross-sectoral strategies to tackle complex or ‘wicked’ problems [5]. However, this approach may not represent the most efficient or effective approach to reducing disease burden at the population level. Rather, it may act to spread finite resources less intensively over a greater number of programs and initiatives, diluting the potential impact of investment [5].

Knowledge mobilisation to support evidence-based decision-making

The term knowledge mobilisation (KM) is used to refer to a range of active approaches deployed to encourage the creation and sharing of research-informed knowledge [2]. The number of terms used to describe KM activities is large [16] and have been widely debated. These terms include knowledge translation, knowledge transfer, knowledge to action, knowledge exchange, knowledge interaction, etc. [2]. This multiplicity of terms can be a barrier to clear communication in this field [2]. In this research, the term KM is preferred as it reflects that the process of producing and applying knowledge in the health sector is non-linear and iterative. KM can involve a number of activities, including capacity building, advocacy, implementation, research and evaluation [17]. Not all of these activities are applied in every KM project [17] and they can be applied in different orders; however, they share the common function of generating and sharing research-informed knowledge [2].

KM strategies have been applied to a range of issues, including the quality and effectiveness of health services, addressing policy questions (for example, mapping health inequity and healthcare disparities), and addressing managerial and organisational issues such as the composition of multidisciplinary teams and the costs and consequences of different service models [2, 18]. A key strategy of KM is the production of good quality, synthesised evidence [9] such as scoping reviews, systematic reviews, meta analyses and research summaries highlighting key findings for decision-makers [9, 10].

Traditional methods of KM via evidence synthesis have made a valuable contribution; however, they have a number of characteristics that limit their utility as decision support methods for complex policy questions. Firstly, systematic reviews and meta-analyses focus on clear and specific questions and therefore have a narrow focus of investigation and limited potential to examine complex questions [11, 19]. Secondly, these methods frequently exclude
Qualitative evidence, and when qualitative evidence is included it is not used to answer the primary research question but only to answer supportive questions such as whether an intervention was acceptable to consumers [19]. Thirdly, these methods produce static overviews of the evidence and policy options that are passively provided to decision-makers, leaving them to interpret that evidence in their localised context and to navigate complexity and uncertainty as they weigh up options for responding to the problem [20].

While there are many KM approaches and techniques, the evaluation of their use is still in its infancy [2, 21]. The limited focus on evaluation of the effectiveness of KM methods, including systems-based ones, has been attributed to the challenges associated with the evaluation task [2], including the methodological challenges of conducting rigorous evaluations. It can be difficult to measure impact, to attribute impact to different strands of the activity in a complex environment, and to minimise the evaluation reporting burden on stakeholders [2].

**Systems approaches to knowledge mobilisation**

There are acknowledged synergies between KM and systems science [21]. Systems science methods have emerged as an effective analytical approach with the capacity to examine both complex health problems and the context in which they are embedded [6, 22, 23]. Systems science can be used to map health system components and their interactions; synthesise evidence, examine and compare the potential outcomes of interventions; and guide more efficient investment and conscientious disinvestment of resources [5]. As practical systems-based KM tools and strategies emerge, their efficacy needs to be evaluated and this knowledge to be shared [2, 21].

Systems approaches recognise the highly contextualised nature of health services and communities and, therefore, evidence to inform decision-makers is unlikely to be in the form of prescriptive statements of ‘what works’ [24]. Rather, evidence from a systems-thinking perspective will suggest the range of strategies that will have different types of effects for different groups under certain conditions. Building this type of evidence base will involve undertaking diverse methodologies, including the use of case studies investigating the efficacy of using systems techniques to inform decision-making [24].

Research methods in prevention science have traditionally employed a reductionist approach focusing on the detail of each component of the system. For example, many studies focus on the design, measurement and analysis of specific interventions for specific target groups. These studies have contributed and will continue to contribute significantly to understanding the effectiveness of prevention interventions, gaining knowledge about direct causal relationships and understanding components of complex systems [6, 25]. However, this approach can result in a failure to achieve understanding of the broader system behaviour influencing prevention problems and can hinder insights that may be critical for effective policy and program decision-making [25]. Traditional statistical methods have difficulty accounting for delays between cause and effect, non-linear relationships and unanticipated consequences of interventions [23].

Applying a systems approach through dynamic simulation modelling can provide a method to map, visualise and quantify a complex system, to promote discussion among stakeholders [26], and to identify points of high leverage for intervening. Leverage points are those places in a system where a small shift can create a large impact [27]. Leverage points are difficult to identify in complex systems using traditional reductionist research methods which examine relationships between specific elements of the system in isolation [28–30]. It is also difficult to identify the direction of shift required to obtain the desired outcome without comprehensive analysis and understanding of the system and its behaviour [27, 31]. Unanticipated consequences of interventions can have profound and negative impacts [31, 32], and can lead to policy resistance in which the intended positive impact of the intervention is counteracted by system responses to the intervention itself [32].

Dynamic simulation models allow for rapid integration and use of new evidence for policy analysis, make trade-offs of policy options explicit, and act as a vehicle for advancing controversial, contested and value-laden debates [5, 31, 33]. Their use to explore the implications of policy options can give rise to policy scenarios that have not previously been considered [5].

System dynamics modelling has been used as a tool to represent disease prevalence, risk factors and local context and to simulate the health outcomes of interventions, thus facilitating the alignment of prevention efforts by a range of community stakeholders [34]. For example, Loyo et al. [35] used a stakeholder engagement process to develop a system dynamics model to simulate the impact of various interventions in chronic disease outcomes. The model was used to illustrate which interventions were most effective leverage points in the local context/system and therefore to align and mobilise prevention efforts of community stakeholders [35].

Participatory modelling processes, such as the one described by Loyo et al. [35], provide an opportunity to understand and develop efficient solutions in the health sector [36, 37]. Participatory modelling, firstly, helps community stakeholders understand how multiple variables, factors and interventions interact. Secondly, simulation modelling can test the potential impact of programs and policies in the ‘safety’ of a virtual environment before they are implemented, saving time, effort, costs and resources. Thirdly, modelling demonstrates potential secondary and
tertiary effects (and even unintended consequences) of intervention strategies. Fourthly, modelling can guide and prioritise data collection and facilitate dialogue among stakeholders [36].

The process of participatory simulation modelling involves engaging multidisciplinary stakeholders in a group model-building process and can be used in conjunction with a number of modelling methods [31, 37, 38]. The value of this engagement is the development of a shared mental model of the causal pathways and potential intervention points in the system [39]. A participatory modelling approach enhances stakeholder knowledge and understanding of the system and its dynamics in varying conditions. It identifies and clarifies complex and contested real world problems [33] and the impact of solutions, therefore facilitating the development of action statements based on the evidence [39, 40]. The involvement of key decision-makers in the model development and validation increases their sense of ownership and confidence that the model is valid for their local context. They are therefore more likely to draw on the outputs to inform decisions about priority interventions and policies [23, 37, 39, 41].

**Important gaps in knowledge**

The application of systems thinking to health improvement is acknowledged as an ongoing challenge [42, 43]. Stakeholder engagement and involvement in the modelling process has been particularly lacking, resulting in unsuccessful projects [42] and a reluctance from ‘non-researchers’ to use models as a decision support tool [33]. A systematic review of the use of simulation modelling to inform surgical patient flow processes found that only half of publications stated that they had produced a model to inform policymakers and health service managers and only 26% actually included policymakers and health service managers in the simulation modelling process [44]. Where policymakers have been included in the simulation modelling process there remains an absence of rigorous analysis of their perspectives on the utility of the model, their learning relating to the development and use of the model, and their commitment to implement the findings of the model [5, 37].

Relationships and collaborations are routinely identified as a key factor in systems approaches [45] and this is particularly true for participatory modelling processes. Important elements for implementing successful systems thinking to address complex issues include the formation of networks and teams, distributed leadership, and strong and effective communication and feedback mechanisms [17]. Understanding the role of participants within the system as well as in the participatory modelling process and bridging professional cultures [45] is key to understanding the factors that will impact on the uptake of simulation modelling as an evidence synthesis tool. Participatory modelling approaches aim to combine multidisciplinary stakeholder perspectives to tackle the social complexity of problems and recognise that different types of knowledge contribute alternative and valuable perspectives to the problem discourse [33].

Evaluation of the participatory simulation modelling process in the health sector has been lacking [5, 41] despite assessment of its efficacy being essential to inform decision-making [5, 37]. Understanding the intricacies of the participatory process [33] and evaluating methods and tools to facilitate participatory modelling is necessary to improve modelling outcomes [4, 31, 37] and further research is required to develop and refine rigorous evaluation methods [39]. The Challenge and Reconstruct Learning (CHaRL) Framework has been proposed by Smajgl and Ward [46] to evaluate participatory modelling processes. This framework can be used for deliberative approaches [47] and involves assessing formalised and facilitated learning among decision-makers and decision influencers at varied policy levels. The key component of the CHaRL framework is the change in perception or belief about assumed causality within the system. In other words, participants’ mental models are challenged by the presentation of different perspectives, scientific evidence and system interactions through the modelling process. The change in mental model can be measured using individual value and attitude/belief orientations recorded by participants pre- and post- the modelling process [46].

**Study objectives**

The objectives of the research are to apply and evaluate a simulation modelling approach, using gestational diabetes as a case study to:

1. Pilot simulation modelling to optimise the use of evidence to inform policy and program decision-making by synthesising and integrating diverse evidence sources into a dynamic simulation model of gestational diabetes using a participatory modelling approach. The model will be used to understand the complex interrelation of factors that drive gestational diabetes mellitus (GDM) rates and test options for interventions.

2. Investigate the perceived value and efficacy of participatory simulation modelling methods as an evidence synthesis and decision support method in an applied health sector context.

**Using GDM as a case study**

GDM is a complication of pregnancy that is defined as carbohydrate intolerance resulting in hyperglycaemia (abnormally high blood sugar) of variable severity with onset or first recognition during pregnancy [48]. GDM defined in this way includes women with undiagnosed pre-existing diabetes, as well as those for whom the first onset is during
pregnancy (especially during the third trimester of pregnancy). The prevalence of GDM is increasing both in Australia and internationally [49].

Identified risk factors for GDM include maternal body mass index of at least 30 kg/m² [50–52], increasing maternal age [52], physical inactivity [50, 52], increasing parity, and ethnicity [53]. Women are also at increased risk if they have a history of GDM [52], previously had a macrosomic baby (birthweight greater than 4000 g), a family history of diabetes [52], polycystic ovary syndrome [52], or a diet low in fibre [54, 55].

Perinatal risks associated with GDM include macrosomia, shoulder dystocia, other birth injuries, hypoglycaemia and perinatal mortality [53, 56]. Long-term risks for the infant from GDM include sustained impairment of glucose tolerance [57], subsequent obesity [58] (although not when adjusted for size) [59], and impaired intellectual achievement [60]. For women, gestational diabetes is a strong risk factor for the development of diabetes later in life [61, 62].

Although the risks associated with gestational diabetes are well recognised, debate remains as to whether screening and treatment to reduce maternal glucose levels reduce these risks [53, 63]. Given this uncertainty, professional groups disagree on whether to recommend routine screening, selective screening based on risk factors for gestational diabetes, or no screening [53]. There is also debate over the efficacy of using a single raised blood glucose result to diagnose GDM [63].

The Australian diagnostic threshold for GDM was changed to be consistent with WHO criteria from January 1, 2015. The WHO report from which the criteria were obtained acknowledges that the evidence for the threshold chosen is weak. However, they argue that the benefits of treatment, i.e. reduction of risk for macrosomia, shoulder dystocia and pre-eclampsia is sufficient justification. Treatment of gestational diabetes once diagnosed is generally medicalised (insulin treatment) and involves intense use of health services, mostly in the third trimester. Investigations of the cost implications of using the lowered diagnostic threshold concluded that cost effectiveness will only be achieved if treatment reduces the risk of caesarean section birth and developing Type 2 diabetes mellitus [64, 65].

Pregnancy has been identified as a point in the life cycle where individuals have increased motivation to commit to health improving behaviours, for example, in smoking cessation [66]. A diagnosis of GDM (or even a glucose tolerance test result that approaches the diagnostic cut-off) may provide a powerful leverage point for multidisciplinary health interventions promoting lifestyle change to reduce the risk of developing diabetes later in life. Almost all women (95%) with a diagnosis of borderline GDM in an Australian study identified that managing their borderline GDM was important or very important for the health of their baby and themselves [67]. Enablers identified by women to implement lifestyle change during pregnancy include family support [66, 67], physical access to programs, knowledge (about diet, exercise and GDM), and motivation levels [67].

Previous models of GDM developed to investigate the cost effectiveness of screening and treatment regimens [64, 65, 68, 69] have provided valuable evidence to inform decision-making. However, these models focussed on an economic evaluation of specific treatments and did not analyse the wider outcomes of policy and program decisions, including the intended and unintended consequences and resource implications of interventions delivered in the health system [70]. Dynamic simulation modelling has been used to investigate the intergenerational impact of GDM on the development of Type 2 diabetes mellitus among First Nations and other population groups in Canada [71]. This model included representations of factors contributing to the development of diabetes mellitus, including changes in behaviour regarding diet and physical activity over time and found that GDM disproportionately contributed to the development of Type 2 diabetes mellitus in First Nations populations compared with other population groups [71].

Dynamic simulation modelling provides an opportunity to explore and compare the implications of health intervention options for GDM services in the Australian Capital Territory (ACT) and to inform policy and program decision-making. The simulations derived from the model can be used to explore the dynamic interaction of risk factors such as maternal weight and weight gain (pre and during pregnancy); the impact of screening earlier or later in pregnancy; the impact of universal or selective screening; the impact of lowering the diagnosis threshold on the number of women diagnosed, health outcomes and health system impacts; the implications of intervention options for prevention and treatment of GDM with different target groups and with different timings (e.g. at the start of pregnancy, during pregnancies, between pregnancies); GDM diagnosis and risk of later development of Type 2 diabetes in the ACT; and the short- and long-term outcomes for mother and baby following treatment for GDM.

The current research project will contribute to knowledge on the application of systems thinking to a localised health system case study by undertaking, validating and evaluating a participatory simulation modelling process focusing on GDM.

**Methods/Design**

**Design overview**

The study design will use mixed methods to achieve the research objectives. A participatory simulation modelling approach will be used to synthesise evidence and explore
strategies for GDM diagnosis, early intervention and management (Objective 1). Evaluation of the modelling process as a systems-based knowledge synthesis tool will incorporate both qualitative and quantitative methods (Objective 2).

Research questions
Simulation modelling will be used to answer the following research questions about GDM interventions in the ACT. Model simulations will explore:

- The dynamic interaction between risk factors such as pre-pregnancy maternal weight, maternal weight gain during pregnancy, GDM diagnosis and life-time risk of developing of Type 2 diabetes for mothers and babies in the ACT
- The short- and long-term outcomes for mother and baby following treatment for GDM in the ACT
- The impact of changing the diagnosis threshold on the number of women diagnosed, health outcomes and the health system impacts (including health economic analysis)
- Health outcomes achieved from priority interventions identified by participants
- Cost effectiveness of priority interventions identified by participants

This research will also explore the effectiveness of participatory simulation modelling methods to optimise the use of evidence to inform policy and program decision-making through qualitative and quantitative methods investigating the participatory modelling process and evidence of impact on decision-making (detailed further below). The specific questions to be answered by this research include:

- Whether simulation modelling is an effective tool to facilitate evidence-informed decision-making in an applied health setting
- The efficacy of applying a participatory approach to model development
- The benefits and limitations of using simulation modelling to explore potential outcomes from a range of policy and intervention options to inform decision-making

Study setting
The study is being conducted as part of an ongoing initiative of The Australian Prevention Partnership Centre to apply systems approaches to the prevention of chronic disease. The research will be carried out at the ACT Government Health Directorate, which provides publicly funded health services for a population of approximately 390,000 in the ACT and is the major health referral centre for the Greater Southern Region of NSW. The total catchment area population is over 600,000 people. Tertiary level maternity services are provided by Canberra Hospital at the Centenary Hospital for Women. There are two publicly funded hospitals and one private hospital in the ACT, providing maternity services.

The number of women giving birth in the ACT is over 6000 per year. Approximately 15% of these women are not ACT residents but access services in the ACT for high risk pregnancy complications (i.e. requiring tertiary level care). There a number of models of antenatal maternity care provided in the ACT including hospital-based outpatient care, tertiary level care, private midwifery care, and shared care (which is integrated with primary healthcare providers).

A specialist gestational diabetes service with satellite clinics in community health centres works with generalist maternity services to provide education and health services for women with gestational diabetes.

Participants
Purposive sampling will be used to recruit participants with a range of expertise such as endocrinology, obstetrics, neonatology, diabetes education, nursing, midwifery, policy, health economics, exercise physiology, pathology, public health, research, allied health, health service management, consumers (healthcare recipients) and the simulation modelling expert team. The anticipated number of participants is 10 to 15 to allow for wide engagement with influential leaders while maintaining a manageable dialogue with meaningful contributions from all members.

The inclusion criteria for participants is that they are recognised experts in providing care, planning services, undertaking research or developing policy for the diagnosis and management of GDM. Participants must also be willing to attend model development and application sessions and participate in the evaluation.

Participants in the group model building and model validation processes will be asked to provide written consent prior to participating.

Procedure
Objective 1 – Participatory model development

Model development
This research will employ a participatory simulation modelling process, which will involve the following steps [4, 26, 31, 36]:

- Forming an expert sub-group of the participants listed above who will define the boundaries of the model. A model is not able to include in detail every possible factor, relationship and intervention, and therefore only those that are relevant to the policy and practice questions to be answered by the model should be included in the first instance. Engaging with the literature and collaborating with stakeholders
and researchers to understand the risk factors for GDM, options for GDM diagnosis and intervention, and reach agreement on the priority health and economic outcome indicators to be included in the model structure

- Identifying data sources and populating the model with data (parameterising the model)
- Deciding which local and/or national data on current practices and behaviours should be incorporated into the model
- Identifying potential intervention leverage points and mapping the mechanism by which interventions have their effect in the model
- Validating the model using accepted validation methods such as assessment of face validity, system behaviour reproduction, parameter estimation, sensitivity analysis and statistical testing [41]
- As the model develops into a functioning simulation tool, exploring possible scenarios and prediction of outcomes
- Ensuring the purpose, assumptions and limitations of the model are clearly stated
- Using the final model to explore the timing, frequency and combination of interventions that deliver optimal impact

The participatory model development process will identify the factors to be represented in the model. It is anticipated that a combination of high level aggregated, individual characteristics and interactions and event-based factors (e.g. service utilisation), will be identified. Therefore, a more flexible hybrid modelling approach will be adopted incorporating system dynamics, agent-based and discrete event modelling methods.

System dynamics modelling methods were created in the 1950s by Jay Forrester in the field of engineering. System dynamics modelling utilises feedback loops (causal loop diagrams) and stock (accumulations) and flow diagrams to represent complex systems [6, 23, 72]. This modelling method represents the dynamics of the system at a high level of abstraction [6], making them an efficient form of modelling in terms of computing resources. System dynamics simulates patterns and trends in system behaviour. Simulation experiments can be used to compare and contrast intervention alternatives to inform decision-making [70].

Agent-based modelling (ABM) methods have been developed more recently and allow for representation of individuals or agents within the system. The model can be built from the ground up by defining agents, their behaviours and their interactions [6, 72]. ABM is a computational method used to examine the actions of agents (e.g. individuals) situated in an environment (e.g. neighbourhood). ABMs specify decision rules controlling dynamics such as ‘If–Then’ statements and mechanistic interactions among agents. When the program is run, agents interact with one another and their environment, often resulting in counterintuitive insights about behaviour of agents and the system [23]. Incorporating ABM components allows flexibility to incorporate the dynamics of people making decisions affecting population health outcomes, and thus efficient planning of healthcare interventions [70].

Discrete event modelling methods represent the system as a process, namely, as a sequence of operations or events performed across entities [72]. For example, discrete event methods are frequently used to represent and improve efficiency of health services such as emergency departments. This modelling method represents complex systems at a low level of abstraction. The core concepts in discrete event simulation (DES) are events, entities, attributes and resources. An event happens at a certain time point in the environment and can affect resources and/or entities. Entities have attributes and consume resources while experiencing events, but consumption is not affected by individual-level behaviour. Attributes are features or characteristics unique to an entity. They can change over time or not. Resources are objects that provide a service to an entity. Queues are another important concept in DES and occur when several entities compete for a specific resource for which there is a constraint [70]. DES modelling is useful to analyse resource utilisation, throughput of services and the impact of varying policy decisions [70].

Advances in modelling software technology now enable multiple modelling methods to be integrated [72]. This allows for modellers to represent the many interacting components of a system and the complex interplay between individual behaviour and social connections across populations [6].

**Model application** Once the model develops into a functioning simulation tool it will be used to explore possible scenarios and prediction of outcomes. During this phase, a broader stakeholder group will be formed and engaged in policy/strategy dialogues facilitated by interaction with the model and explore the costs and benefits for a range of intervention options. The composition of the stakeholder group will include the full scope of disciplines and consumers outlined in the Participants section. The model application process aims to refine the model as well as to demonstrate the utility of the model to key decision-makers so as to inform policy action and program decisions.

The transdisciplinary simulation modelling process provides an opportunity to establish network relationships and analyse policy and program options based on outcomes simulated. An action statement regarding GDM diagnosis and treatment in the ACT based on the simulation
modelling work and synthesised evidence will be developed with the expert group.

Data analysis The model will be built using AnyLogic® 7.2, St Petersburg, Russian Federation. AnyLogic® software allows for multiple modelling methods to be integrated into a single hybrid model providing participants both flexibility and transparency in model design.

Model parameterisation involves populating the model with data and will evolve in accordance with the participatory modelling process. This will make use of the following:

- Secondary analysis of de-identified administrative data to inform transitions (hazard rates/probabilities/relationships between risk factors) within the model structure. For example, regression analyses may be conducted to determine the contribution of gestational diabetes in relation to other risk factors to perinatal outcomes such as birthweight
- Published demographic information such as age and gender characteristics, age-specific fertility rates, population estimates of weight status categories
- Published results from research on intervention effects such as the impact of targeted pregnancy weight management programs focused on nutrition or physical activity on the development of GDM
- Local expert knowledge to supplement available data
- Partitioned administrative and/or available survey data to calibrate the model

Statistical analysis of administrative data will be conducted using IBM SPSS Statistics version 22, United States. Data availability is a potential limitation to this study. It is proposed that, where data is not of high quality or is not available, placeholder values will be used and tested using the following methods. Firstly, the model simulations will be analysed against trends and patterns observed in historical data and, secondly, sensitivity testing will be conducted around the missing values to determine if the model outputs depend significantly on them. When parameters are identified that the model is sensitive too, this can be used to guide and prioritise future research activities to obtain these important pieces of data. Assumptions surrounding the use of placeholder values will be made explicit in descriptions of the methods used to develop the model.

Validation of the model is necessary to assess the logic, soundness and utility of the model outputs [41]. Validation of the model can be conducted as part of the model development process by conducting tests and involving the model users in assessing the validity of the model [73].

The model will be validated using accepted validation methods such as assessment of face validity, system behaviour reproduction, parameter estimation, sensitivity analysis and statistical testing [41]. Expert participants in the model development process will be asked to assess whether the model and its behaviour and outputs are reasonable given their knowledge of the system [73]. The model behaviour will also be tested against historical data and model simulations over time will be assessed. Available data will be partitioned with a subset used to build the model and the remaining data used to determine (or test) whether the model replicates the historical system behaviour [73]. Parameter variability and sensitivity analyses will also be conducted to test model behaviour and to determine which parameters the model is most sensitive too. Those parameters that are sensitive, that is they cause significant changes in the model's behaviour or output, should be made sufficiently accurate prior to using the model [73].

Objective 2 – Evaluation of a participatory approach to dynamic simulation model building

Procedure The case study methodology allows for investigation of the strengths, weaknesses and evaluation of participatory simulation modelling as a mechanism to influence policy and program decision-making and develop action statements [2]. Little is known about the value, strengths and limitations of simulation modelling as applied to ‘real world’ health policy decision-making. The key research questions addressed in this study include those relating to engagement of experts in the process; perceived commitment, influence and confidence of stakeholders in implementing policy and program decisions identified in the modelling process; and measuring the impact of the process in terms of policy and program change.

The evaluation of the participatory modelling process is informed by the CHaRL Framework proposed by Smajgl and Ward [46]. The CHaRL framework can be used for deliberative approaches and involves assessing formalised and facilitated learning among decision-makers and decision influencers at varied policy levels. The key component of the CHaRL framework is the change in perception or belief about assumed causality within the system. In other words, participants' mental models are challenged by the presentation of different perspectives, scientific evidence and system interactions through the modelling process. The change in mental model can be measured using individual value and attitude/belief orientations recorded by participants before and after the modelling process [46].

Therefore, the evaluation methods to determine the effectiveness and impact of systems dynamic modelling will include investigating the:

- Participation in the process, e.g. response rate to invitations, attendance and retention at modelling sessions and subsequent deliberative forums
Participants’ perceptions of the key factors that contribute to GDM and the best use of resources to diagnose and manage GDM through survey responses

Group interactions, contributions and engagement with the process by qualitative analysis of audio recordings of the model building and engagement sessions

Informant views via semi-structured interview on the:
- value of simulation modelling as an evidence synthesis tool
- strengths and limitations and intention to use simulation modelling in the future
- perceived enablers and barriers to the use of simulation modelling
- personal response to the participatory modelling process
- Follow-up environment scan to determine policy and program decisions that were informed by the modelling process and the model outputs

Data analysis

Quantitative analyses will include measuring and reporting the number of sessions attended, and analysing the responses recorded on the before and after forum surveys.

Participants will be asked to record their views on the main contributing factors to GDM, the optimal time for screening for GDM and how they would allocate resources to a hypothetical new service for women with GDM. They will also be asked to provide self-reported evaluation feedback reflecting on their learning and ways to improve the modelling sessions.

Qualitative analyses will include analysing the data collected during:

1. Model development sessions
2. Model application sessions
3. Semi-structured interviews (pre- and post-modelling workshops)
4. Notes and memos based on meetings and de-identified conversations with participants and the modelling team

The model development and application sessions will be audio recorded, primarily to allow the investigators to review content information and expert advice provided by participants relating to model development. The recordings, participant observations and field notes will be kept to highlight particularly valuable comments and analyse behaviours or interactions between participants. The analysis of field notes will be triangulated against the audio recordings and interview transcripts.

Semi-structured interviews will be conducted with participants of the model development and model application sessions. Participants will be purposively selected for interviews to provide a range of perspectives and interviews will be conducted face-to-face where possible.

The main domains to be covered will include participant’s perceptions or ‘mental model’ of GDM through the modelling process, value of simulation modelling as an evidence synthesis methodology to inform decision-making, and intention to use this method in the future. The proposed interview questions are contained in Box 1.

**Box 1 Semi-structured interview questions to obtain key informant views**

**Prior to workshops**

Based on your experience, what are the current challenges that GDM services are facing? What do you think is driving these challenges? What changes do you think GDM services need to make to cope with these challenges? Which interventions would you prioritise to prevent and manage GDM?

Could you talk a little about your thoughts on evidence-based decision-making in the health policy context? To what extent do you think evidence is used to inform health policy and program decisions? What factors have you found to be useful to support its use? What are the main challenges?

Have you had experience using results of evidence synthesis methods such as systematic reviews, meta-analyses? Did they meet your needs for evidence to inform your decision-making? From your experience, what are the strengths and limitations of these methods? What other forms of evidence do you use in decision-making?

Have you participated in any form of simulation modelling process before? (If reply yes) Could you tell me about the modelling process and your experience of it? In your opinion, what are the benefits and limitations of simulation modelling as an evidence synthesis tool?

**Post workshops**

Could you tell me about your experience of participating in the simulation modelling process? What are the strengths and weaknesses of simulation modelling as an evidence synthesis tool?

Has/How has the modelling process influenced your opinion of the key factors that contribute to GDM? Has/How has the modelling process influenced your opinion of the best use of resources to screen for and treat GDM?

Will you use the outcomes of the gestational diabetes modelling process to guide your future decision-making? Why or why not?

Based on your experience would you say simulation modelling is worthwhile for health sector policy/practice settings? Why/why not?

Do you intend to use the outputs of this model or participate in other simulation modelling projects in the future? Why or why not?

In your opinion, what would you say are facilitators and barriers to the use of simulation modelling to synthesise evidence for decision-making?

Do you have any recommendations to improve the process for using simulation modelling as an evidence synthesis tool?
Field notes relating to meetings and informal discussions will be maintained by the researcher in a journal format and will be included in the qualitative data analysis.

Audio recordings will be transcribed and integrated with field notes and reflections. Transcriptions will be de-identified, collated and coded so that only general themes emerge.

Interview data will be independently coded by two investigators. Initial codes will be derived from the research aims and subsequently refined over two coding cycles. The two coders will compare and agree upon codes and emerging themes at the end of each cycle, resolving disagreement by consensus opinion or by the creation of new, mutually agreeable, codes/themes.

Data analysis will be iterative and begin with identifying central organising concepts, patterns and themes from the coded data. Thematic analysis will be reflective and revised by revisiting the coded and collated data to ensure that identified themes and subthemes are coherent, distinctively relevant to the research question [74].

Common and repeated themes identified from the modelling sessions will be investigated through interviews to better understand informant views in relation to specific topics, and to assess the strength and importance of various themes. A comparative analysis will be conducted to understand the range of participant views in relation to their role perspective and level of power within their organisation, e.g. clinician, researcher, manager and policymaker views.

This research involves investigators who currently work within the local health sector. This provides some advantage as these investigators have good knowledge of the system and context; however, it also presents challenges and limitations. For example, the investigators’ willingness to identify and report on system limitations may be impacted by their professional affiliation with the organisation. The involvement of external co-investigators and the use of independent reporting mechanisms through The Australian Prevention Partnership Centre are mitigation strategies to be employed for this challenge. The use of voluntary recruitment processes and confidentialised analyses of individual input and participation will be employed to address perceptions of coercion or concerns of repercussion from either participating or declining to participate in this research.

A follow-up environment scan to determine policy and program decisions that were informed by the modelling process and the model outputs will be conducted three to 6 months after the model engagement workshops. This will involve interviews with end users and document analyses to determine the use of model outputs to inform decision-making.

**Data storage and management**

All audio-recorded data from the model development and model application sessions will be de-identified by using codes instead of names and removing any potentially identifying text from transcripts. Data will be stored securely on password protected computers or ACT Health secure servers and will only be accessible to the researchers.

Paper surveys will be anonymised and scanned to create an electronic file to be stored in secure folders on a secure server only accessible to the researchers. The paper surveys will then be securely destroyed. Clinical and administrative data to be used for the project will be de-identified prior to analysis.

**Discussion**

This project will apply systems science and simulation modelling to GDM in the ACT as a case study.

The outcomes will include, firstly, producing a model that will be a functioning simulation tool to explore possible scenarios and the impact of those scenarios on health outcomes for the mother and baby as well as service impacts for the health system; secondly, developing a joint commitment for policy action and program decisions through engagement with the stakeholder group and, thirdly, evaluating the use of simulation modelling to inform decision-making.

The participatory model-building process will be informed by a multidisciplinary expert stakeholder group. This provides an opportunity to ensure the model reflects the shared understanding of the causal pathways and potential intervention points in the system.

Simulation modelling methods will be used to explore and compare strategies for GDM diagnosis, early intervention and management. The modelling will include interaction between risk factors, the short- and long-term outcomes for mother and baby, and potential modes and timing of intervention.

Importantly, involving key decision-makers and experts in the model development and validation process increases the acceptability of the model for the local context. The model is therefore more likely to be useful to inform decisions about priority interventions and policies.

Systems science is emerging as an effective way to examine both complex health problems and their context. It can be used to synthesise evidence, examine and compare potential outcomes of policy options, and guide the best use of limited resources through methods such as simulation modelling. This research will contribute to existing knowledge, firstly, by applying a participatory process to simulation modelling in a local health setting; the participatory process will engage expert stakeholders in the development of a functioning model to inform decision-making. Secondly, by developing and incorporating evaluation methods to investigate the efficacy of simulation modelling as an evidence synthesis tool. Thirdly, by using quantitative data to develop a simulation model to inform health policy and program decisions.
Abbreviations

AMT: Agent-based modelling; ACT: Australian Capital Territory; CHeRL: Challenge and Reconstruct Learning; DES: Discrete event simulation; GDM: Gestational diabetes mellitus; KM: Knowledge mobilisation

Acknowledgements

The authors acknowledge the valuable contributions of Associate Professor Alison Hayes, University of Sydney and Associate Professor Paul Dugdale, Australian National University, who reviewed an earlier version of this manuscript.

Funding statement

This project is being financially supported by The Australian Prevention Partnership Centre (TAPPC). TAPPC is funded from 2013–18 by the National Health and Medical Research Council (NHMRC) with co-funding from the Australian Government Department of Health, the NSW Ministry of Health, ACT Health, HCF, and the HCF Research Foundation. TAPPC’s focus is working in partnership to address chronic disease.

Financial support from TAPPC for this project includes:

- Financial support to run modelling workshops, provide modelling supervision and PhD supervision.
- PhD top-up scholarship (2015–18).

University of Notre Dame have provided the following financial support:

- Australian Postgraduate Award scholarship.
- CRN top-up scholarship for supervision travel expenses.

Authors’ contributions

LF conceptualised the manuscript and wrote the first draft. All authors have made important intellectual contributions to multiple draft revisions. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

This research has been reviewed and approved as low risk by the ACT Health Human Research Ethics Committee (ACTHLR.15.150) and the University of Notre Dame Human Research Ethics Committee (0151195).

Author details

1ACT Health, GPO Box 825, Canberra ACT 2601, Australia. 2The Australian Prevention Partnership Centre, Sax Institute, PO Box K617, Haymarket NSW 1240 Sydney, Australia. 3School of Medicine, University of Notre Dame, PO Box 9442007 Sydney, Australia. 4Australian National University, Canberra ACT 2601, Australia. 5University of New South Wales, Sydney, NSW 2052, Australia.

Received: 5 July 2016 Accepted: 5 September 2016

Published online: 21 September 2016

References

2. Davies HTO, Powell AE, Nutley SM. Mobilising Knowledge to Improve UK

World Health Organization. Bridging the

References

Received: 5 July 2016 Accepted: 5 September 2016

Published online: 21 September 2016

References

2. Davies HTO, Powell AE, Nutley SM. Mobilising Knowledge to Improve UK

World Health Organization. Bridging the

References

Received: 5 July 2016 Accepted: 5 September 2016

Published online: 21 September 2016

References

2. Davies HTO, Powell AE, Nutley SM. Mobilising Knowledge to Improve UK

World Health Organization. Bridging the

References

Received: 5 July 2016 Accepted: 5 September 2016

Published online: 21 September 2016

References

2. Davies HTO, Powell AE, Nutley SM. Mobilising Knowledge to Improve UK


Chapter 3: Research methods

Section 3.1 in this chapter presents the published research protocol. This paper also explored the challenges associated with achieving evidence-based health policy making, and how system science applications to knowledge mobilisation, such as participatory DSM, have potential to overcome these challenges. Important gaps in knowledge are identified, including firstly, whether it is feasible to use a participatory approach to dynamic simulation modelling as a method for evidence synthesis and decision support in “real-world” public health settings. Secondly, what are the perceived value and efficacy of participatory simulation modelling methods from the perspective of end users.

Section 3.2 describes how the research methods evolved following publication of the research protocol. Section 3.3 describes my role in the primary DIP case study and the two supplementary case studies to examine the participatory DSM approach. Also included in Section 3.3 is a summary of the research questions, and their relationship to the study objectives, data sources, and the other chapters in thesis. Section 3.4 provides the relevant information about the ethics approvals for this research.

3.1 Paper 1: Simulation modelling as a tool for knowledge mobilisation in health policy settings: a case study protocol

3.2 Evolution of research methods following publication of the protocol

My overall study objectives, from the protocol paper above, were to:

1. Pilot simulation modelling to optimise the use of evidence to inform policy and program decision-making by synthesising and integrating diverse evidence sources into a DSM of gestational diabetes using a participatory modelling approach.
2. Investigate the perceived value and efficacy of participatory simulation modelling methods as an evidence synthesis and decision support method in an applied health sector context.

As the study progressed following the publication of the protocol paper, further developments to the study methods were implemented. These developments included modifications to the scope of the DIP case study model, and triangulation of data compiled about the value of PSM in this case study with additional data from two other modelling projects conducted under the auspices of the Australian Prevention Partnership Centre. These developments are described below.

3.2.1 Revised model scope for DIP case study (study objective 1)

The case study scope was expanded during the model development process from initially including only gestational diabetes mellitus to including all forms of diabetes in pregnancy. Diabetes in pregnancy includes both diabetes diagnosed during pregnancy, i.e. gestational diabetes mellitus (GDM), and pre-existing diabetes. While most women who experience diabetes in pregnancy have GDM, participants identified during the first model development workshop that the number of pregnant women presenting to services with pre-existing Type 2 diabetes is increasing, and that these women have more complex care needs. Therefore, as the model development progressed, the participants identified pre-existing Type 2 diabetes as a priority for inclusion in the model. Type 2 diabetes was also identified as being of interest from a broader public health perspective as many of the risk factors are amenable to lifestyle interventions.
3.2.2 Expanded perspective on the value of participatory dynamic simulation modelling - triangulation of data from other modelling projects (study objective 2)

The investigation into the value of participatory simulation modelling in health policy and program decision making (objective 2) was expanded to include the perspectives of participants from two other modelling projects (Table 1). These additional simulation modelling case-studies used the same participatory processes to develop DSMs for use in applied health policy settings under the auspices of The Australian Prevention Partnership Centre. However, only the primary DIP case-study was accompanied by a concurrent program of research to study the participatory modelling process – as reported in this thesis.

Triangulation is defined as the collection of information using more than one method, including more than one perspective and more than one sample [1]. Triangulation is used to increase the probability that alternative explanations for the phenomena being investigated are uncovered through the use multiple data collection methods, settings and participants [1, 2]. When the data converges, or triangulates, it produces more reliable insights than could be generated from a single method [2]. The decision to draw on participants’ experience from the two other modelling projects strengthened the research by allowing the triangulation of data collected in other Australian public health policy settings, and at different stages of model maturity.

My data collection methods for all three case studies included modelling workshop observations, field notes and interviews with the participants of the model development workshops. End-user participants from the three DSM projects (Table 1) were invited to participate in semi-structured interviews to discuss their experiences of the modelling workshops, and their perspectives on the application and impact of participatory simulation modelling on health policy and program decision making. My role in each project is described below in Section 3.3 and summarised in Table 2.
Table 1: Description of dynamic simulation modelling case studies and context. (modified from Chapter 4: Decision makers experience of participatory dynamic simulation modelling methods for public health policy paper)

<table>
<thead>
<tr>
<th>Topic area</th>
<th>Type of model</th>
<th>Model development period</th>
<th>Context</th>
<th>Application to decision making</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention and management of Diabetes in Pregnancy (DIP)</td>
<td>Tripartite model (system dynamics, agent based modelling and discrete event simulation)</td>
<td>2016 - 2018</td>
<td>Diabetes in pregnancy (DIP) is increasing in Australia, and diabetes services are having difficulty meeting demand with existing resources. This DSM focused on DIP from a local perspective. It considered the short, intermediate, and long-term implications of the increasing prevalence of risk factors for DIP. Prevention of risk factors was prioritised in the model as small delays in the development of diabetes will have implications for the longer-term burden of disease and costs to the health system.</td>
<td>The model informs the investments for intervention in DIP, including both clinical and population health interventions. Workload and resource use have been incorporated into the model to enable it to act as a resource allocation decision support tool</td>
</tr>
<tr>
<td>Reduction of alcohol-related harms (Alcohol)</td>
<td>Agent based model</td>
<td>2015 - 2016</td>
<td>This project was implemented as a collaboration between The Australian Prevention Partnership Centre, a state department of health, local and national alcohol researchers, clinicians and program planners to inform strategies for reducing alcohol-related harms.</td>
<td>The model captures the heterogeneity of drinking behaviours across the state population, the dynamics of those drinking behaviours across the life course, the acute and chronic harms that arise and the differential effects of interventions across subgroups in the population.</td>
</tr>
<tr>
<td>Reduction of childhood overweight and obesity (Obesity)</td>
<td>System dynamics model</td>
<td>2016</td>
<td>In September 2015, an Australian State Premier unveiled an ambitious target to reduce childhood overweight and obesity in children by five per cent over 10 years. Based on population projections and the anticipated impact of enhancing the existing suite of interventions delivered, it was estimated that additional strategies, or combinations of strategies, would be required to achieve the Premier’s target. However, the complexity of the problem and uncertainty about where best to target resources and efforts presented a challenge to decision makers.</td>
<td>The model tests the likely impacts of a range of policies and programs and informs the combination of interventions that might achieve the Premier’s target.</td>
</tr>
</tbody>
</table>
3.3 Candidate’s role in research activities

Participatory action research is highly collaborative [2]. It involves extensive teamwork between researchers and partners throughout the research process; from identifying the problem to disseminating the results [3]. The modelling case studies included in this thesis involved the contribution of many people, however all of the research reported in the published papers that form the basis of this thesis was led by me. This section aims to distinguish and clarify my role in the implementation of the participatory process for each case study, the model development for the primary case study, and the qualitative data collection and analysis. My role in the case-study development, implementation, and associated research activities for the primary case study (DIP model), and in additional case studies, is summarised in Table 2. In summary, I led all of the work for the DIP case study, as well as the supplementary data collection and analysis of participants’ experiences in the two additional case studies focusing on childhood overweight and obesity and reducing alcohol related harms. A detailed overview of my study objectives, research questions and data sources is provided in Section 3.3.1. The details of my roles in the model development for diabetes in pregnancy, and the qualitative data collection and analysis are described below in Sections 3.3.3 and 3.3.4 respectively.

For the primary case study of DIP, I was the project lead and led all activities including: project conceptualisation and design, initial engagement with the lead domain experts; recruiting participants to the expert modelling consortium; planning, organising and facilitating workshops and meetings; managing stakeholder relationships; managing the core model development team (excluding technical supervision of the model programming). I also led the analysing of evidence and providing of relevant data to inform the model (Table 2). The core deliberative and analytical processes involved in the participatory approach are described in detail in Chapters 4 to 6 and are not repeated here.
<table>
<thead>
<tr>
<th>Case study implementation and research activity led by me</th>
<th>Prevention and management of Diabetes in Pregnancy (DIP)</th>
<th>Reduction of alcohol-related harms (Alcohol)</th>
<th>Reduction of childhood overweight and obesity (Obesity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project conception, design and planning (paper 1)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workshop planning, organisation and facilitation</td>
<td>✔</td>
<td>Planning advice</td>
<td>Planning advice</td>
</tr>
<tr>
<td>Engaging / collaborating with lead domain expert (a)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observational data collection, and advice on workshop implementation</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Stakeholder coordination and management for expert modelling consortium (b)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core model development team (c) management</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data provision (including statistical analysis) to guide model development</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant observations, analysis of recordings and field notes from participatory modelling workshops (papers 2 and 3)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Qualitative data collection and analysis of deliberations and decisions in model development process (paper 3)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interviews with end-user participants - data collection and analysis (paper 4)</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Translating outcomes of participatory model development process for technical programming of DIP model (paper 5)</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:  
(a) Domain expert – well-respected authority on the focus issue who can play a lead role in the project planning and workshop facilitation.  
(b) Modelling consortium – the broader group of expert participants who participated in the model development process. These were people with a range of expertise, including providing or planning health services, undertaking research or developing policy for the issue in focus.  
(c) Core model development team or group – a smaller core group of computer scientists, computer science students, research officers, public health practitioners, and medical specialists who met frequently with the project lead to progress the model.
3.3.1 Expanded summary of research questions and data sources

The overall objectives of this research were to examine the utility and feasibility of using participatory DSM in applied health sector contexts; and to investigate the perceived value and efficacy of the approach as an evidence synthesis and decision support method. I conducted an in-depth examination of the primary case study (DIP) and two additional case studies (alcohol and obesity) to determine the elements and strategies involved in successful implementation, the overall challenges and opportunities arising from the participatory approach, the nature of the analytic deliberations and decision-making processes, and the end user perspectives of its value and utility. The research questions that were examined to achieve the study objectives are outlined below and aligned with the reported findings in Chapters 4 to 7.

The primary research questions addressed in Chapter 4 were: “how does participatory DSM build on current knowledge mobilisation best practice?” and “How can participants be engaged actively to successfully contribute their expert knowledge to the participatory process?”. In this chapter, I examined and described the participatory activities and stakeholder engagement strategies utilised across the three case studies and related them to knowledge mobilisation principles and practice.

Chapter 5 focused on the primary case study (DIP) and explored the overall research questions: “what were the analytical processes involved in converting the qualitative conceptual map, developed collaboratively with participants, into a quantified DSM?”; and “what were the decision-making processes involved in developing a rigorous DSM to answer current policy and program questions for diabetes in pregnancy prevention and management?”. I analysed the workshop and meeting recordings, and triangulated this data with field notes and other documentation to uncover the deliberative methods and decisions involved.

I explored the value of participatory DSM from the perspectives of end-user decision-maker participants in Chapter 6. The paper in this chapter focused on the following research questions: “What was the experience of participating in the interactive model building
activities like for end-user participants?”, “What were the benefits and challenges of the approach from their perspective?”, “What did participants learn from engaging in the participatory model development process?” and “How were they using the DSMs to inform policy and program decisions?”. I interviewed participants from the DIP case study before and after the participatory modelling process, and the participants from the two additional case studies after their participatory process to gain their perspectives on the efficacy and value of the approach to inform decision making.

The DIP model and outputs are described in Chapter 7. This chapter addressed the research questions in relation to DIP as outlined in the protocol paper, and provides information about the many data sources used to inform the model. The research questions addressed by the model included: “How does the dynamic interaction between risk factors impact on DIP development”; “What are the short- and long-term outcomes for mother and baby following diabetes in pregnancy?”, and “What is the impact of prevention interventions prioritised by participants on incidence of DIP and individual health outcomes?”. An overview of the research questions explored, the data sources used to answer them, and their relationship to each of the two study objectives is provided in Table 3. Further detail about the data collection and analyses is provided in Sections 3.3.3 to 3.3.5.
### Table 3: Overview of research questions and data sources used to investigate the objectives

<table>
<thead>
<tr>
<th>Research questions and associated papers within this thesis:</th>
<th>Relates to objective:</th>
<th>Data sources:</th>
<th>Thesis Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How does participatory DSM build on knowledge mobilisation best practice? (paper 2)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>4</td>
</tr>
<tr>
<td>How can participants be engaged to facilitate their expert knowledge contribution to the process? (paper 2)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>4</td>
</tr>
<tr>
<td>What were the analytical processes involved in converting conceptual systems maps to quantified simulation models? (paper 3)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>5</td>
</tr>
<tr>
<td>What were the decision-making processes involved in producing a rigorous DSM to answer health service and policy questions relating to diabetes in pregnancy? (paper 3)</td>
<td>1</td>
<td>✔ ✔ ✔</td>
<td>5, 7</td>
</tr>
<tr>
<td>What was the experience of participating in the interactive model building activities like for end-user participants? (paper 4)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>6</td>
</tr>
<tr>
<td>What were the benefits and challenges of the approach from their perspective? (paper 4)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>6</td>
</tr>
<tr>
<td>What did end-user participants learn from being involved? (paper 4)</td>
<td>1, 2</td>
<td>✔ ✔</td>
<td>6</td>
</tr>
<tr>
<td>How were the case study models being used to inform policy and program decisions? (paper 4)</td>
<td>1, 2</td>
<td>✔ ✔ ✔</td>
<td>6</td>
</tr>
<tr>
<td>How does the dynamic interaction between risk factors impact on development of DIP? (paper 5)</td>
<td>1</td>
<td>✔ ✔</td>
<td>7</td>
</tr>
<tr>
<td>What are the short- and long-term outcomes for mothers and babies following DIP? (paper 5)</td>
<td>1</td>
<td>✔ ✔</td>
<td>7</td>
</tr>
<tr>
<td>What is the impact of prioritised prevention interventions on DIP incidence and individual health outcomes? (paper 5)</td>
<td>1</td>
<td>✔ ✔</td>
<td>7</td>
</tr>
</tbody>
</table>
3.3.2 Search strategy and literature compilation

In addition to the comprehensive literature review presented in Chapter 2, each paper in this thesis includes a literature review section to provide an overview of current knowledge and to situate the research. A range of search terms were used to identify relevant research. These were utilised regularly to search PubMed, Google Scholar and Medline (OVID) databases. The list of terms here is not exhaustive and is included to provide an overview of the literature domains that informed this research. The main search terms included: “knowledge mobilis(z)ation”, “knowledge translation”, “knowledge transfer”, “participatory action research health”, “dynamic simulation”, “agent-based model”, “system dynamics”, “hybrid modelling”, “participatory modelling”, “group model building”, “co-production health”, “interdisciplinary research health”, “participatory research”, “diabetes and pregnancy”, “gestational diabetes”, “prevent* diabetes and pregnancy”, “collaborative research”, “population health modelling”, “health policy decision support”, “social policy decision support”, “epidemiologic methods”, “policy modelling”, “modelling guidelines”, “selecting modelling methods”, “systems science (thinking) and population health” and “evidence based policy health”. Notifications were set up in Google Scholar and ResearchGate to alert me to new published research on topics of interest using the search terms listed above. The identified literature was stored and categorised in Endnote version 9. Additional research was identified and recommended by my supervisors, other collaborators and colleagues, and from reference lists of the papers identified during database searches. The literature was reviewed and synthesised under “questions”, or topics, that were refined iteratively throughout this PhD research and eventually formed the literature review in Chapter 2.

3.3.3 Diabetes in pregnancy model development

The technical computer programming for the DIP model development process was undertaken in collaboration with the Computational Epidemiology and Public Health Informatics Laboratory (CEPHIL), Department of Computer Science, University of Saskatchewan. Under the supervision of Professor Nathaniel Osgood, three post graduate students took responsibility for implementing the technical development of the DIP model. I was the primary conduit between the technical modellers and the participatory modelling
consortium (the participant stakeholders). In addition to all communication with participants, I facilitated regular model development meetings and frequent communication with the technical modellers to contribute to and guide the model development. This often involved translating the technical modellers’ questions into the language of the DIP expert stakeholders, and in return translating the input from our expert stakeholder group back to the modellers. The model development was informed by the decisions of the core model development group (led by me), and incorporated the input of the wider stakeholder engagement process with the modelling consortium that I also facilitated. I summarised the outcomes of the participatory process activities for input into the model by the technical modellers. Over the course of the projects, two of the post-graduate students were outposted from CEPHIL to The Australian Prevention Partnership Centre to work on the model and another student worked on the model while based at CEPHIL. This collaboration enabled the development of a sophisticated multi-method model which leveraged the knowledge gained from previous diabetes modelling projects undertaken at CEPHIL [4-7], while being developed to meet the decision requirements of local stakeholders within ACT Health.

Dynamic simulation models require significant data and evidence, and the compilation and synthesis of this evidence was an important additional analytical role I undertook in the model development process. I searched for and reviewed evidence from published meta-analyses, systematic reviews, individual studies, population surveys, census and administrative health service data. All of the statistical analysis of survey, census and administrative data to inform and/or validate the model was also carried out by me. More information about the data analysis and evidence synthesis processes involved in informing DSMs is provided in Chapter 6. The data sources used in the DIP model are described in detail in the model documentation in Chapter 7.

3.3.4 Model development for the two additional case studies

The two additional modelling case study projects were undertaken by The Australian Prevention Partnership Centre, in collaboration with the Centre for Population Health, NSW Ministry of Health. These projects were undertaken to inform policy and strategy dialogues in NSW for the prevention of alcohol-related harm and for the reduction and prevention of childhood overweight and obesity. The technical programming for the additional case
studies was undertaken by members of the Decision Analytics team and was led by Associate Professor Jo-An Atkinson, Dr Geoff McDonnell and Mr Mark Heffernan. Further information about these projects is available here: https://preventioncentre.org.au/resources/dynamic_simulation_modelling/.

3.3.5 Qualitative data collection and analysis

A qualitative approach was chosen for this research as it provides flexible and useful research methods, which combine effectively with a participatory action research framework [2, 3, 8]. As outlined in Chapter 2, the core principles of participatory modelling include planning stakeholder engagement; being aware of social dynamics, power, and special interests within the participatory group; flexibility in the process; openness and transparency; and encouraging learning through the process. Qualitative analysis can provide rich and detailed, yet complex, meaning from data collected using a variety of methods including interviews, recordings, observations and document analysis [9, 10]. The participatory process involved interactive stakeholder workshops, small group meetings and written communications (mostly by email). The observations and recordings of workshops and meetings, together with email communications and written documents were important data sources arising from the participatory research process that provided insights into the core principles outlined above. Further data were collected via semi-structured interviews to provide individual perspectives from participants, both about their expectations prior to participation and reflecting on their experience of the process and the core principles post-participation. The methods used to collect and analyse data for this thesis are described below.

Participant observations, recordings and analysis of participatory model development process

The participatory model development workshops for the three case study projects were held during 2015 to 2017 (details reported in Chapters 4 to 6). Further model development meetings for the primary case study (DIP model) were held during 2018. For the primary DIP case study, the participatory workshops, web-based meetings with participants and some core model development group meetings were recorded with participants’ consent to facilitate the in-depth analysis of the model development process (Chapter 5).
For the two supplementary case studies, I also documented participatory field notes based on observations of the workshops, and subsequent debriefing discussions between myself, my supervisors and the project officers working on those case studies (Eloise O’Donnell, Nick Roberts, Jacqueline Davison and Christine Whittall - see acknowledgements). Debriefing discussions occurred either immediately following or within one week of the participatory workshops, and the field notes were compiled at this time. I also prepared further follow up summaries of all our discussions. The primary role for the above-named project officers from The Australian Prevention Partnership Centre was to provide administrative and logistic support for the NSW participatory modelling workshops. One project officer (NR) also played an active role in facilitating the workshops for the obesity project. Those project officers with particular areas of content expertise also joined as participants some of the small group model development activities.

In the debriefing sessions I led the discussions to focus on reviewing the participatory activities, and identifying what had worked well, and what hadn’t worked well. The possible reasons were explored based on observations of group dynamics, level of engagement from participants, and conversations with participants during and after the workshops. Strategies to address any issues or concerns about participation, engagement or representation in the workshops were discussed and actioned where appropriate. For example, observers identified that some participants had not been contributing to a discussion when another expert was perceived to have greater authority. This observation was used to modify the facilitation of subsequent workshops to ensure that all participants were provided with a range of opportunities to contribute e.g. in small and large group activities, and through individual discussions.

All of the workshop and meeting recordings and field notes were reviewed, coded and analysed by me. The data coding and analysis for the workshops and meetings used thematic analysis that was guided by the “theoretical” approach to thematic analysis described by Braun and Clarke [9]. The focus research questions (Table 3) for this thematic analysis (reported in Chapter 5) were: What were the key elements and features of the participatory approach that were required to successfully develop a policy relevant DSM from a qualitative systems map? What types of questions were asked by the stakeholders, what concerns and issues were raised, and what was the feedback from participants during
the process? What challenges and tensions arose in the process and how were they managed?

After I had listened to and coded each recording, I reviewed the coding notes and used coloured highlighting to identify themes. An analytic memo was written for each coded recording to highlight important themes and concepts identified from the coding process. I used worksheets in Microsoft Excel to compare data collected from each workshop or meeting and to collate the data into important themes and categories. The progressive analysis involved an iterative process of coding and analytical memos to develop themes and conceptual categories and explore their inter-relationships. The analysis was iteratively reviewed and refined as new data became available and themes and insights identified were triangulated across the different data types and sources. The analyses were iteratively discussed with and reviewed by my supervisors, Jo-An Atkinson and Lucie Rychetnik, and my analytic memos were also shared with them to facilitate the analysis review process.

**Interviews with participant stakeholders pre- and post-participatory process**

I conducted pre-process interviews with participants in the DIP case-study in April and May 2016 and post-process interviews with participants across all three case studies in September and October 2017. Two pre-process interviews were unable to be conducted by me, and Ms Eloise O’Donnell (project officer within the Australian Prevention Partnership Centre) conducted these two interviews using my interview schedule. All other interviews and all of the data analysis were conducted by me. The interviews took place in the participant’s workplace, or if that was not possible, via telephone or web-conferencing. Each interview lasted between 30 and 60 minutes. Face-to-face and telephone interviews were of comparable quality and length and telephone interviews were particularly useful in enabling me to speak with experts in distant locations throughout Australia and overseas.

I used a semi-structured interview format, with questions and prompts designed to elicit the interviewee’s views (indicative questions are shown in Box 1 in the published research protocol, included above in this Chapter). I began each interview with the consent process (either written or verbal), and an introduction broadly outlining the topics for the interview questions. A common occurrence in the pre-process interviews was interviewees expressing a concern that they had little or no experience with DSM, and thus they were
uncertain as to what they could contribute to the project. Therefore, I provided those participants with a preliminary explanation of what participatory DSM involved, and explained the rationale for their role in the model development process as expert participant stakeholders.

For the post-process interviews with end-users I explained that I was interested in hearing about their experience of participating in a modelling project; and that I was collecting information from end-user participants on the value and impact of this type of modelling from three different settings and at different stages of model maturity. I also emphasised that I was interested in hearing their honest perceptions of the pros and cons of the participatory modelling methods. Although the broad topic areas were the same across all interviews, I tailored some of the questions to the local project-specific experience of the interviewees. Indicative questions are shown in the supplementary material for the paper presented in Chapter 6. As my data collection and analysis progressed, I adapted my question prompts to elicit further information that I had identified from previous interviews as being interesting or important. I continued recruiting end-user participants until I found that no new concepts or ideas were being raised during the interviews.

All interviews were recorded and professionally transcribed as soon as practicable. After each interview I wrote a short memo which included some brief information about the participant, their role in the modelling projects, my initial impressions from our discussion and any new information and ideas that had emerged from the interview. Once each interview transcript was available, I checked and corrected the transcription while listening to the recording. I then deleted any identifying information.

The interview data analysis process was guided by methods of grounded theory [10, 11]. Using Microsoft Word, I formatted the transcripts into three columns with the first indicating the speaker (i.e. interviewer or interviewee), the second column contained the transcription and my analysis codes were entered in the third column. After each transcription was checked for accuracy, I read them again, highlighting phrases and concepts that seemed important and entering codes in the third column. Initially I used line-by-line coding to become familiar with the data and to ensure that I did not miss any important concepts. I made use of gerunds to focus my analysis on actions and processes and to make explicit the connections between the data, concepts and themes [11].
common themes and core concepts emerged from the data, I used colour coded highlighting to easily identify these within my codes. I also applied the colour coding to highlight sections of text from the transcripts that were enlightening for a particular theme or category, and potentially useful for direct quote examples. After each transcript had been coded, I reviewed the interview memos and added additional information based on my analysis. After all the interviews had been analysed, I returned to the first transcripts to review the coding and memos for alignment with my later analysis and added further insights to my analytical memos.

Following the detailed coding process, I transitioned to focused coding to categorise the data into the common and important conceptual groupings that had emerged from the analysis [10, 11]. This process involved reviewing the line-by-line coding, reviewing the transcript text and comparing across interviews to identify the dominant and most important thematic and conceptual categories in the data. I used worksheets in Microsoft Excel to collate the focused codes and to analyse the data across interviews. Where I had highlighted transcripts as particularly important or insightful, I transferred these direct quotes into the worksheets. For Chapter 6, the findings from the interview data were then triangulated with further analysis of other data collected from the three case-studies including: analysis of group process, email exchanges, participant observations I had recorded, notes from workshop debriefing meetings, field notes and memos based on meetings and de-identified discussions with participants and the modelling team. Analytical memos for each key theme were further developed and integrated across the sources of data.

3.4 Ethics approvals

I obtained ethics approval for my research from the University of Notre Dame, Australia Human Research Ethics Committee (015119S) and the ACT Health Human Research Ethics Committee (ETHLR.15.150). The committees specifically approved my participant information sheet and consent form. The documentation is included in Appendices 2 and 3.
An amendment was submitted to and approved by both committees in July 2017 to interview participants from additional modelling projects to explore their experience and perceived value of participatory DSM.

All participants gave individual consent. Those who were interviewed in person were given the consent form to read, and all signed it. Those who were interviewed over the telephone were sent the consent form and returned it prior to the interview being conducted. Participants were informed that they were free to withdraw from the study at any stage, but none have withdrawn. All the participants were assured confidentiality, and because of the relatively small pool of participants, steps were taken to preserve anonymity in the findings. For example, when providing information on the professional roles of quoted experts in my published papers I did not provide sub-specialty information, preferring to use more general descriptors such as “clinician” or “public health professional”.

Appendices for Chapter 3


2. Ethics approval letters from:
   - ACT Health Human Research Ethics Committee; and
   - University of Notre Dame Australia Human Research Ethics Committee.

3. Participant Information Sheets and Consent Forms

4. Participatory workshop one report – Diabetes in Pregnancy in the ACT


6. Participatory workshop two report – Diabetes in Pregnancy in the ACT

References


