Mental health systems modelling for evidence-informed service reform in Australia

Alliance for Mental Health Systems Modelling (Acumen)

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Abstract

Australia's Fifth National Mental Health Plan required governments to report, not only on the progress of changes to mental health service delivery, but to also plan for services that should be provided. Future population demand for treatment and care is challenging to predict and one solution involves modelling the uncertain demands on the system. Modelling can help decision-makers understand likely future changes in mental health service demand and more intelligently choose appropriate responses. It can also support greater scrutiny, accountability and transparency of these processes. Australia has an emerging national capacity for systems modelling in mental health which can enhance the next phase of mental health reform. This paper introduces concepts useful for understanding mental health modelling and identifies where modelling approaches can support health service planners to make evidence-informed decisions regarding planning and investment for the Australian population.

Keywords

mental health planning, service delivery, modelling

Declarations

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Introduction

Mental disorders impose a substantial health, social and economic burden worldwide (Bloom et al., 2011; Ferrari et al., 2022), but mental health service systems in most if not all countries are underfinanced, poorly organised and not able to contribute as they could to reducing these burdens (Saxena et al., 2007; Whiteford et al., 2016). In Australia, it is increasingly difficult for the current mental health system to provide equitable, effective and cost-effective care at the population level, with large-scale systemic reforms recommended by recent public inquiries (Productivity Commission, 2020; State of Victoria, 2021; National Mental Health Commission, 2014). Some of the recommended reforms target the social and environmental determinants of mental health and illness which fall outside the traditional health system. Other recommendations emphasise that mental health service planning should properly reflect local or regional needs, and not be directed only by centralised decision making (Council of Australian Governments Health Council, 2017). Successful reform, within the health sector or beyond, is dependent on accurate information about the current system performance and agreed directions on what the system should deliver, notwithstanding the uncertainty associated with complex national and regional reforms.

A key challenge for mental health decision makers is that the demand for treatment and care is constantly evolving and challenging to predict. One solution to these uncertain demands is for models of the system to be developed, a range of responses to be simulated, and likely outcomes projected. Mental health system models are representations of health service components, along with social, economic and environmental characteristics that shape the mental health of populations. Using models to describe key features of the systems and forecast how they might change over time under different conditions can lead to more accountable, transparent and ideally less uncertain decision-making.

Acumen, the Alliance for Mental Health Systems Models (https://www.acumen-mh.org/) was created in 2020 and includes Australian researchers experienced in population epidemiology, mental health services modelling, health economic evaluation and mental health policy and planning. The aim of Acumen is to help planners meet the mental health needs of communities, by:

- providing access to the best available decision support tools to inform mental health policy and planning;
- providing a national reference point for expert advice and best practice in evidence-based mental health systems modelling;

- developing the capacity of policy makers and service planners to successfully use mental health systems models on the ground;
- fostering collaboration, promoting data sharing and reducing duplication of effort amongst mental health system modellers; and
- providing scientific peer review and expert recommendations to relevant parties that could be provided as tools to assist regional mental health planning.

In this paper, we: (1) describe the policy context and decision support requirements relevant to mental health systems modelling; (2) briefly introduce some of the concepts useful for understanding mental health systems modelling; and (3) identify and discuss different approaches to mental health systems modelling and how these relate to better mental health policy and systems design.

The decision environment in mental health service planning

Australian mental health policy context

Australia adopted a National Mental Health Strategy in 1993, to be implemented in successive five-year mental health plans. The first three plans (1993-2009) assessed progress through regular reporting of changes in funding and services in each state and territory. The Fourth National Mental Health Plan (2009-2014) shifted the approach, from retrospectively tracking changes, to requiring that jurisdictions plan and report on mental health services that should be provided in the future. The Fifth National Mental Health and Suicide Prevention Plan in 2017 required the Commonwealth-funded Primary Health Networks (PHNs) and state and territory government Local Hospital Networks (LHNs) to engage in joint regional planning for the population they should jointly serve. However, operationalising joint mental health planning remains complex. Different levels of government rely on different funding streams and often focus on different populations and workforces. These differences tend to split, rather than integrate the service system.

The report from the Productivity Commission Inquiry into Mental Health (Productivity Commission, 2020) found that current guidelines for developing joint regional plans were not sufficiently stringent to effectively facilitate desired outcomes, because they do not prescribe what joint regional plans should contain. The Commission recommended that each regional plan developed jointly by PHNs and LHNs reports a ‘gap analysis’, comparing current services with *what services are required*, and a schedule detailing the level and mix of services that would be provided over the following 3-year period. The need for evidence-informed recommendations to support effective change and inform resource allocation, makes more imperative the use of decision support tools to guide systemic and individual improvement (Rosenberg et al., 2022).

Priority decision support requirements

Service system planners require information in three main areas: (1) the expected level of demand for services; (2) the existing level and distribution of service provision; and (3) the level and mix of services required to meet expected demand, ensuring that services are both effective and cost effective. Implementation then requires information and decisions about (1) the feasibility of and challenges relating to implementing effective, efficient and equitable service provision; and (2) ranking and prioritisation of the sequence of changes and improvements required to close identified service gaps. Decision uncertainty associated with such a dynamic planning context can be partially mitigated through the use of models that can reflect the impacts of changes to the mental health system.

Modelling concepts

Models and modelling

The term "model" has multiple potential definitions, but in the context of health systems, it is typically used to refer to a quantitative representation of a component of the system relevant to the decision making of policymakers and service planners. The main purposes of a model is to make assessments (e.g., understand service gaps), predictions (e.g., how systems respond to changes in external environment) and to forecast when the prediction relates to a future event.

Modelling has been part of longstanding and well-developed health technology assessment (HTA) in Australian government decisions on subsidising pharmaceutical therapies and Medicare-rebated procedural interventions. However, its use has been limited or non-existent in many other areas of Australian healthcare, particularly in areas of health that are not directly funded via the Pharmaceutical Benefits and Medicare Benefits Schemes. National and state and territory responses to the COVID-19 pandemic have, however, demonstrated the use of modelling the transmission and likely impacts of COVID under different assumptions which could be used to help inform investments and actions to control virus transmission, manage critical care service demand, and inform vaccine prioritisation and scale-up strategies (Doherty Institute, 2021; Scott et al., 2021; Moss et al., 2020).

Modelling and simulation methods in mental health, and health more generally, have advanced significantly over the last decade, now helping decision makers at national, state, and regional levels to understand the likely trajectory of mental health outcomes and future service demand (both at the system and services level) (Whiteford and Diminic, 2020).

Mental health systems models

Compared to traditional planning methods based on combining the historical trajectory of service usage with budgetary adjustments, system models can allow a greater range of relevant sociotechnical factors to inform mental health service planning and policy development. Mental health systems models typically synthesise a range of data (e.g., demography, epidemiology, service utilisation and other social, economic and community drivers of mental health) to forecast likely demand for healthcare and optimise responses to the demand for healthcare. Practical applications of systems modelling include decision aids to help understand the potential joint action of combinations of interventions and investments, and to anticipate the downstream consequences of isolated interventions that may merely defer problems or displace them to other parts of the system. Similarly, mental health systems models may be particularly useful for supporting regional planning initiatives that account for the unique needs and characteristics of an area of interest.

In mental health, systems models have been used as interactive decision support tools to simulate and weight alternatives to deliver strategic, impactful and cost-effective solutions, despite the complexity and uncertainty of forward planning (Long and Meadows, 2017; Occhipinti et al., 2021a; Occhipinti et al., 2021c; Atkinson et al., 2019; Atkinson et al., 2020b). Systems modelling can also enable more holistic approaches to mental health policy-making that account for the broad range of mental health determinants that lie beyond the healthcare system and the manner in which public policies beyond healthcare impact on population mental health (Furst et al., 2021).

Tailoring modelling approaches to decision contexts

Mental health systems are a complex, location-based, social and technical system that does not exist in neatly separable parts (Plsek and Greenhalgh, 2001). It is nonetheless useful and necessary to understand the parts, and how they interact, to better understand the behaviour of the whole. Any individual model will typically focus on representing only a simplified subset of system features that are most relevant to the decision topic being explored.

The identification of salient system features will, in turn, shape the type of modelling technique to be used. Different methods are indicated depending on whether the features of primary interest are resources, trends, health states, cost-effectiveness, population flows or service processes. Some of the different types of models that have been developed and applied to forecast, evaluate and optimise mental health services are identified in Figure 1. These models vary in statistical design, purpose and complexity and choice of appropriate models normally depend on factors such as modelling questions, available data, project life-cycle and available resources.

Needs-based planning

Needs-based planning models combine projections of future population prevalence and service demands alongside estimates of the quantity and types of services required to respond to these needs, often modelled from theoretical average packages of service interventions/types for specific cohorts with a predicted service need. Such models aim to estimate the mental health system resourcing needed to deliver these services for the overall projected demand, such as workforce, facilities and funding (Asamani et al., 2021). Needs-based planning models generally develop and combine these specific inputs with relatively simple mathematical approaches (Meadows et al., 2020), but could also be used as a framework for incorporating more complex modelling techniques for each model input, such as demand projections. A prominent Australian example of a needs-based planning model is the National Mental Health Service Planning Framework (NMHSPF) (Diminic et al., 2022). The NMHSPF built on earlier Australian needs-based planning models such as Tolkien II (Andrews and Tolkien II Team, 2006) and the New South Wales Mental Health Clinical Care and Prevention (NSW MH-CCP) model (NSW Government Mental Health Branch, 2013). It has been used to support national mental health system reform recommendations (such as those from the Productivity Commission mental health inquiry and Royal Commission into Victoria's Mental Health System), jurisdictional mental health plans (e.g., Queensland Health, 2016; Mental Health Commission, 2019; Government of South Australia, 2019) and integrated joint regional plans developed between PHNs and LHNs (e.g.,Wright et al., 2021; Central and Eastern Sydney Primary Health Network, 2019; Adelaide Primary Health Network, 2020; Gossip et al., 2022).

Statistical learning models

Statistical learning models (e.g., time series forecasting models, spatio-temporal models, causal models) are statistical tools that learn patterns in historical data (e.g., trends, distributions, and associations) to enable prediction of future possibilities or trends. They are data-driven and are commonly used to estimate and forecast the spatial and/or temporal distribution of disorder prevalence, incidence and demands (Soyiri and Reidpath, 2013) or dynamics between services (Almeda et al., 2019). They rely on an assumption that the predictions are determined by structure in existing data (e.g., historical trends, causal associations between variables). In mental health research, they are increasingly used to explore large datasets for purposes that include risk prediction, targeting care and identifying potential targets for prevention and intervention (Iniesta et al., 2016).

Markov models

Markov model (MM) is a general term for a group of models (also called state-transition models) that predict transitions between different health states (e.g., healthy, sick, recovered, dead), and commonly used in mental health simulation. The states in a Markov model can be observed or latent and transitions between them governed by the Markov assumption that transition probabilities are dependent on the present state and not the past. MM can be modelled both at the aggregate (cohort) or individual level, with transition probability either being estimated from data or assumed based on literature or empirical evidence (Hoang et al., 2016). MMs are widely used in mental health service planning and economic evaluation (e.g., to compare treatments individually) (Long and Meadows, 2017), due in part to their relative simplicity in modelling the outcomes of different courses of action over time. Markov models are frequently used in mental health economic evaluations to assist in determining efficient resource allocation. For example, economic evaluation modelling to determine the cost effectiveness of the treatment for eating disorders was used by the Medicare Benefits Schedule Review Taskforce – Eating Disorder Working Group to inform the 2019 Australian Federal Government's decision to introduce 64 new Medicare Benefits Schedule items of the Eating Disorder Treatment and Management Plans (Le et al., 2017a; Le et al., 2017b).

System dynamics models

System dynamics (SD) models (or compartment models) try to capture flows of population aggregates (e.g., how the totals for each age or service sub-group within a population change over time). SD models are not restricted by the assumptions of MM, thereby allowing for interdependencies, feedback and complex designs in the system (Sterman, 2001). As the outputs generated by SD models depend on their feedback structure (Kunc et al., 2018), these models can require significant investment in conceptualisation and validation. Historically, SD models were commonly used in disease epidemiology, though they have been increasingly used in health system research in recent years (Darabi and Hosseinichimeh, 2020). System dynamics models in mental health have examined topics such as patient flows (Long and Meadows, 2017), to understand population level impacts of evidence based interventions (Atkinson et al., 2020a), to proactively respond to crises (Occhipinti et al., 2021b; Occhipinti et al., 2022) and to inform the likely impacts of funding and/or resource reallocation (Occhipinti et al., 2022; Atkinson et al., 2019). Systems dynamic modelling has also been used to provide decision support tools to national and state policy makers and regional planners to forecast future population mental health trajectories and support better allocation of funding and resources. Stratified modelling drawing on population health survey findings can provide guidance as to relative service need between areas of catchment responsibility, for instance estimating variability occasioned by differences in levels of socioeconomic disadvantage (Meadows et al., 2021; Enticott et al., 2016).

Discrete Event Simulation

Discrete Event Simulation (DES) is an individual-based method focusing on modelling the timing and impacts of events occurring within the processes of a service. In health system research, DES offers a flexible tool to model patient pathways through care and identify ways to optimise resource allocation and improve efficiency (Davies and Davies, 1994). It is particularly well suited to describing resource-constrained systems, where events (e.g., contact with a service) occur at discrete points of time and entities (e.g., patients) move through a system of queues with events and wait times governed by probability distributions and the availability of resources (e.g., clinicians). About one in ten mental health simulation studies use DES, particularly among epidemiology and economic evaluation studies (Long and Meadows, 2017). A discrete event simulation approach has been used to identify a critical population for delivery of Mindfulness Based Cognitive Therapy in relapse prevention for depression, with results varying according to expected population acceptability rates (Patten and Meadows, 2009).

Agent-based models

Agent-based models (ABMs) simulate the behaviours of individual agents (e.g., patients, health care providers) and their interactions with other agents and their environment. Compared to other techniques, ABM offers additional flexibility to model heterogeneous individual behaviours and social networks and interactions, as well as learning and adaptation (Bonabeau, 2002). ABMs can be major undertakings to implement and validate given their inherent complexity and detailed microdata requirements. This may explain why they are undertaken less frequently than simpler approaches, although their popularity is growing. ABMs currently account for about one in twenty mental health models, with a particular focus on help-seeking and service access (Long and Meadows, 2017).

Hybrid/blended and other approaches

As each modelling approach has advantages and limitations, increasingly advanced computational technology can integrate two or more types of approaches, creating hybrid or blended models (Cassidy et al., 2019). Blended models can be designed in different ways – e.g., full integration, sequential design and hierarchical design (Swinerd and McNaught, 2012; Lättilä et al., 2010) – with a general aim of taking advantage of multiple levels of abstraction that can be obtained by combining models to improve overall modelling performance. Alternatively, different models can be ensembled (averaged) to obtain more reliable estimates. Ensemble modelling has been increasingly used in infectious disease forecasting (Reich et al., 2019; Cramer et al., 2022) and burden of disease modelling (Bannick et al., 2020; Vos et al., 2020), but is a less common approach used in mental health system simulations.

In other cases, comprehensive information on context and services (e.g., service availability, capacity and workforce, resource utilisation and outcomes) can be integrated using techniques not limited to approaches described above for more complex purposes. For example, models for accessing Relative Technical Efficiency (RTE) can be used to support decision-making in health care (García-Alonso et al., 2019). RET evaluates the relative efficiency of decision-making units (DMUs) (e.g., types of services or catchment areas) combining information on context and services, (e.g., using local atlases of mental healthcare based on the Description and Evaluation of Services and Directories - DESDE) (Van Spijker et al., 2019), administrative health databases, as well as advance modelling techniques such as simulation engines, and artificial intelligence. RTE has been extensively used in mental health planning in Europe and the US (García-Alonso et al., 2022). In Australia DESDE has been used for describing the capacity and the pattern of care for adults (Fernandez et al., 2017), child and adolescents (Salvador-Carulla et al, in press), drug and alcohol (Calabria et al., 2021), rural and remote areas (Salinas-Perez et al., 2020; Van Spijker et al., 2019), and older populations (Tabatabaei-Jafari et al., 2020). Although local atlases of mental healthcare using DESDE have been produced in Australia, the lack of access to linked databases has hampered the development of DEA/RTE studies.

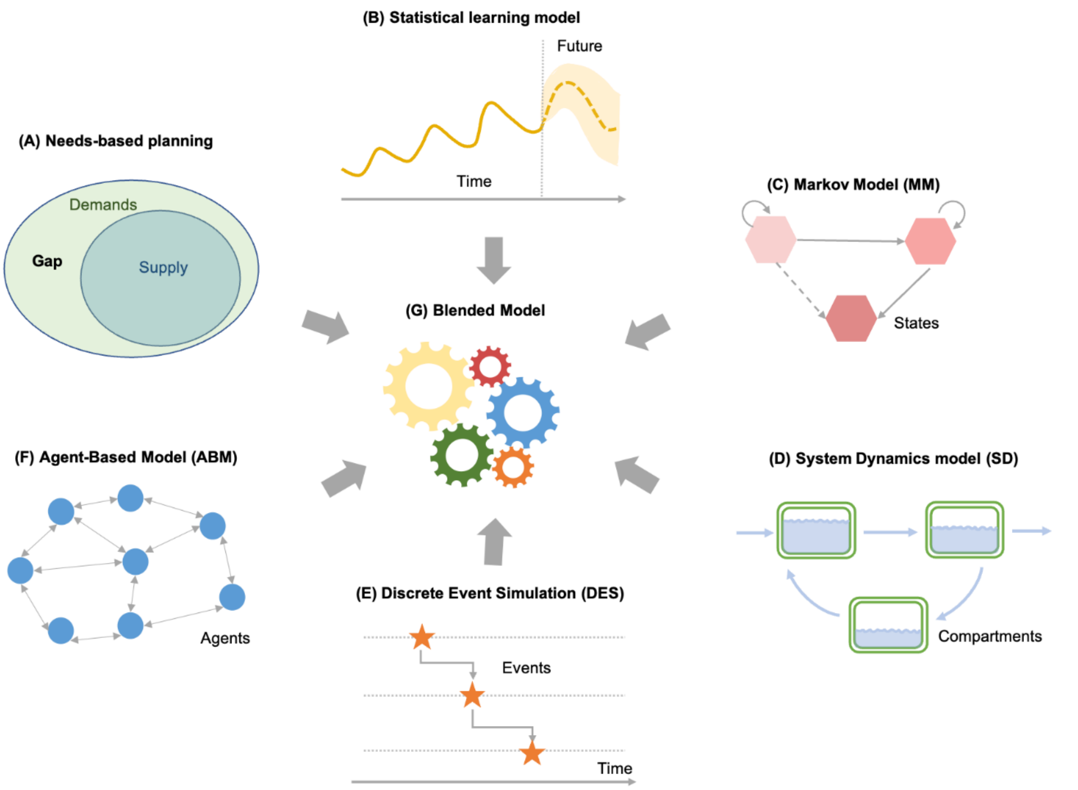

Figure 1. Different approaches for modelling mental health demands and systems. (A) Needs-based planning models aim to forecast future service provision requirements; (B) Statistical learning models aim at exploring patterns in historical data to predict future possibilities or trends under counterfactual conditions; (C) Markov model (MM) simulates transitions between different health states over time; (D) System Dynamics model (SD) models the flows between different compartments (e.g., counts of people flowing from primary to tertiary care) and simulates system behaviour; (E) Discrete Event Simulation (DES) traces the timing and impact of events in processes; (F) Agent-based model (ABM) predicts the behaviours, interactions and adaptation of individual agents; (G) Blended (hybrid) model integrates different types of models.

Economic evaluation framework

Health system models are widely incorporated in the economic evaluation context. Decision analytic modelling is the main framework used in most HTA contexts, which compares both the costs and the consequences (usually health impacts) of alternative courses of action in order to inform investment decisions (Petrou and Gray, 2011). Decision analytic models frequently used in HTA contexts or other decision-making contexts can range from simple decision trees to the types of models considered in this paper. The type of model used should be appropriate to the decision-context including the evidence base of intervention or service effectiveness etc. ISPOR, the professional society of health economics and outcomes research has published a series of best practice papers in the use of modelling (Caro et al., 2012).

Modelling projects

The success of mental health system modelling projects depends on a number of factors that are not specific to the type of frameworks and methods deployed. These key success factors include, for example, appropriate co-design and engagement with stakeholders, reliable input data, robust validation processes, and interactive toolkits (Long et al., 2020). The process of developing a mental health systems model can be broadly described as follows:

Define the research question – develop a well-defined research question to guide the establishment of the modelling framework (Dalkin et al., 2015). The PICOT framework (patient, intervention, comparison, outcome and timing), although not designed specifically for health system simulation, could be used to guide this process (Haynes, 2005).

Model conceptualisation – determine the model type(s) and structure that can best address the research question at hand. The development of a conceptual model is a critical step in model development for which best practice guidance is available (Roberts et al., 2012). In this stage, a combination of literature reviewing and stakeholder engagement can be used to help identify the appropriate model(s). The final choice of model(s) depends on research questions as well as available resources and the project timeline. Model structures will then need to be established outlining the causal pathways between in-scope model parameters (e.g., events or health states), the comparison framework and input data requirements.

Data collection – identify, analyse and synthesise multiple sources of data using best practice methods. The required input data will need to be collected from different sources such as population epidemiology, service delivery data and relevant literature.

Model implementation – operationalise the model structure by incorporating all input data and programming the model. Best practice guidance on model implementation can vary based on the type of model (Marshall et al., 2015a; Marshall et al., 2015b; Karnon et al., 2012; Siebert et al., 2012; Grimm et al., 2010). The results will also need to be integrated when multiple model types are used.

Model verification and validation – perform checks on the model to ensure that the model functions correctly and that it produces results that are in keeping with reality. Best practice guidance on model verification and validation recommends steps that can include comparisons of model predictions to real-world data, the output of other models and the expectations and expertise of stakeholders (Dasbach and Elbasha, 2017; Vemer et al., 2016; Eddy et al., 2012; Gibert et al., 2010).

Model refinement – refine the model based on the results of model testing and stakeholder feedback. Additional data may need to be collected if there is any extension of the modelling scopes.

Sensitivity analysis – perform sensitivity analyses to assess the impact of uncertainty in estimates of the direct effects of each intervention, and / or other key uncertain model input parameters on the simulation results.

Feedback report/tools – interpretation and collation of model findings in a format that is suitable for dissemination to policymakers and stakeholders. Interactive tool(s) can be developed, which can help non-technical users to apply the model and/or visualise results, thereby improving translational impact.

Application – applying insights from modelling to guide changes in policy and service delivery. In this stage, the modeller can work collaboratively with stakeholders to design an implementation plan (e.g., a prospective costing analysis under different roll-out scenarios). The impact of implementation on system operation can then be utilised to improve the design of the modelling framework to close the loop.

Regular engagement and consultation with stakeholders throughout the lifecycle of a modelling project can help ensure that the research question is appropriately defined and that any prospective model produces results that are valid and relevant. Stakeholders include people with lived experience, service providers/clinicians, service managers/directors, government/system planners and policymakers, academic experts, data and technical experts, and others depending on the type of model and research questions. A co-design framework can be applied in some of the critical stages, for example, model conceptualisation and feedback report/tool(s) as described in Figure 2. Such collaborative approaches to model development and use may also serve an educational purpose for non-modellers, helping to improve the models and the use of evidence in decision-making (Sterman, 2006).

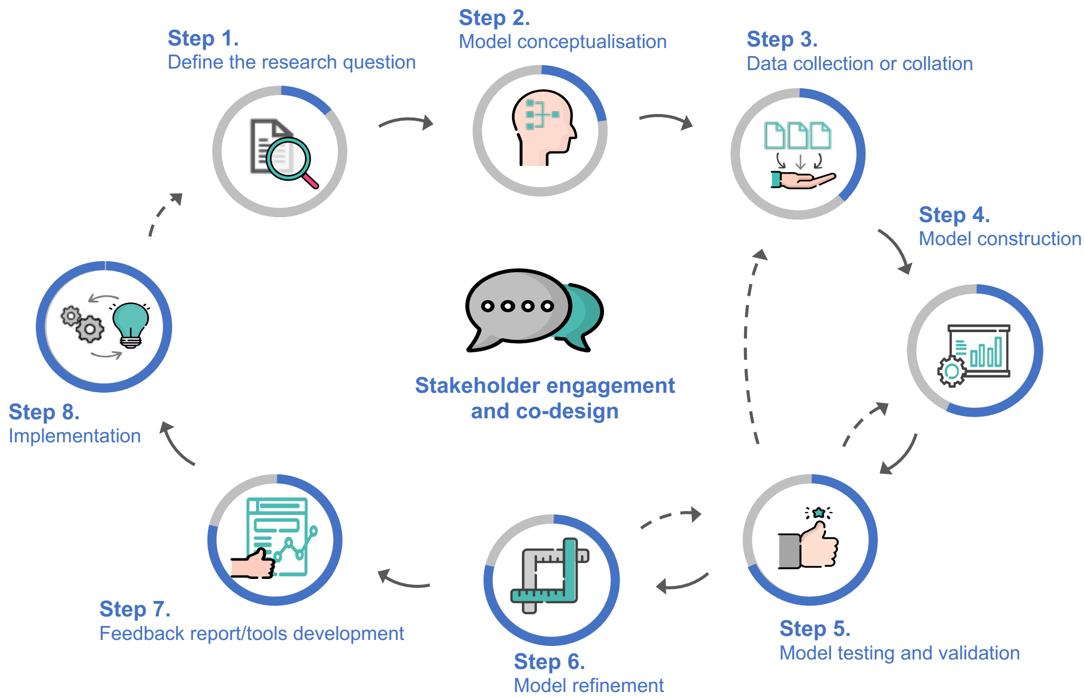

Figure 2. Lifecycle of the health system simulation projects.

Validity and legitimacy

To enhance trust and legitimacy, models need to incorporate high-quality data and be transparently implemented. It is important that mental health policy makers and system planners understand and make judgements about the robustness and suitability of various models for their decision-making needs. As complex health systems models become increasingly popular, the transparency and validation standards they are expected to meet also grow (Feenstra et al., 2021). There is now increasing support for open-source approaches to model development (Long and Meadows, 2017; Pouwels et al., 2022), although barriers around resourcing, ethics and privacy, intellectual property considerations, knowledge and skills have so far prevented widespread adoption of this practice. More generally, improved access to data that is Findable, Accessible, Interoperable and Reusable (FAIR) (Wilkinson et al., 2016) is required to help improve the quality of mental health systems models. However, the data that mental health systems models currently depend on has considerable limitations (Wolpert and Rutter, 2018). Addressing this challenge will involve attitudinal and policy change beyond the mental health modelling community. Too often, legitimate concerns about the need to protect the privacy of mental health data are unnecessarily and unhelpfully extended to a default position of secrecy (Rock and Cross, 2020).

Conclusion

The Australian experience of mental health reform over the past 30 years has demonstrated the limitations and inadequacy of existing mental health planning tools and approaches, such as historical budgeting. While calls for more resources in mental health are commonplace (Productivity Commission, 2020), without the tools for better regional and local planning, consistently used and applied across the mental health sector, there is a risk new resources will fail to address identified problems. Developing the best, evidence-based service modelling is a key step toward optimal service reform. To fully capitalise on the potential impact modelling can make, new resources, training and networks will be needed, to bring together modellers and planners in an organised effort to build and implement the systems needed to drive better, local decision-making.

But it is not the only step. As the World Health Organization says, "health policy-making is an inherently political process in which research evidence is only one, albeit the most important, factor that influences decision making. Scientific evidence often has to compete with beliefs, personal interests, political considerations, traditions, past experience, and financial constraints" (World Health Organization, 2018). Furthermore, priority setting and decision-making in mental health care and health care more generally should not be uncritically based on model outputs. Other considerations that cannot be easily captured by mathematical modelling, such as rule of rescue, need to be incorporated into the decision-making process (Carter et al., 2008; Mihalopoulos et al., 2013). The development of new, improved regional mental health plans must also be accompanied by the appropriate support for implementation. Change is not costless and the failure to effectively implement reform has been a consistent finding in assessments of Australia's National Mental Health Strategy (Productivity Commission, 2020; National Mental Health Commission, 2014).

In addition to effective implementation, there is an urgent requirement to establish accountability. First, to determine if approved regional plans are implemented and second, to assess the impact of new plans on the mental health outcomes of local communities. Advanced modelling and simulation can provide decision makers with important information they need to make measurably better planning decisions, understanding it is "*people (who) deliver systems, facilitate design and manage risk*", not algorithms (Clarkson et al., 2017). Quantification enables accountability and opens the way for greater public understanding, scrutiny, and involvement in healthcare planning at all levels.

Finally, there must be agreement as to what improvement in mental health outcomes means. What will success look like? Is it measured by lower population prevalence of mental disorder, or a broader outcome measure where quality and length of life is included? How to define and measure quality of life then becomes important and needs to be incorporated into the modelling. Engagement of the population being served, as well as local policy and decision-makers, in the determination of preferred outcome measures can shape mental health modelling further, making it more useful in driving reform and building benchmarks for comparison. Australia has an emerging national capacity for system modelling in mental health. This capacity can enhance the next phase of Australia's mental health reform to look forwards to the future we need, and not only backwards to where we have come from.

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