

A framework for an open source economic model of the systems shaping the mental health of young people

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Abstract

Summary: There is strong in principle support for open source health economic models, but practical barriers limit their availability. We propose a set of principles and standards for the implementation of open source health economic models that are TIMELY - Transparent, Iterative, Modular, Epitomised and Yielding. We then describe a software framework that we have developed for developing TIMELY models in youth mental health and illustrate this framework with an open source utility mapping project.

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1 Introduction

Computational models have become essential tools for health policy development [1]. Although influential and widely used, these models routinely contain errors [2], are rarely adequately validated [3], can be difficult to reproduce [4–6] and are likely to be infrequently updated or revised [7]. To help address these issues, there is growing support for greater use of open source health economics models (OSHEMs) that grant liberal permissions to access and re-use model source code [8]. However, to date actual implementations of OSHEMs are rare [9–11]. Barriers to adoption include concerns about intellectual property, confidentiality, model misuse and the resources required to support open source implementations [8,12]. As many health economic models are owned by pharmaceutical companies and consultancies, commercial considerations may also limit the uptake of OSHEMs [11].

There is also a need to develop good practice recommendations for OSHEMs [13]. Adherence to explicit standards is as essential requirement for quality health economic model implementation [1], but current guidance for OSHEMs is scarce and piecemeal. Guidelines on health economic model transparency were published ten years ago [14] and made recommendations on documenting models but notably not on the sharing of model code and data. More recent and more general modelling guidance [1] recommends the sharing of code and data through platforms such as GitHub [15] and Zenodo [16] and the use of version

control systems such as Git [17]. A coding framework for OSHEMs developed in the language R includes standardised approaches to directory structure and naming conventions [18].

We have consolidated and refined these and other recommended standards for OSHEMs as part of a framework for developing an open source model of youth mental health. In this paper, we describe our motivation for developing the framework, the rationale for each included standard, the software toolkits we have developed to help meet each standard and a worked example of a modelling project developed with the framework.

2 Motivation

2.1 Why develop OSHEMs in mental health

Mental disorders impose high health, social and economic burdens worldwide [19,20]. Much of this burden is potentially avertable [21], but poorly financed and organised mental health systems are ill-equipped for this challenge[22,23]. The large and widespread additional mental health burdens recently observed during the COVID pandemic[24] and predicted as a potential future consequence of global heating [25], highlight the need to improve the resilience and adaptability of these systems. To help stem growing demand for mental health services, policymakers have also been encouraged to place greater emphasis on tackling the social determinants of mental disorder[26].

Computational modelling could play an important role in developing policies to improve population mental health but this may require significant changes in the way mental health modelling projects are funded, conceptualised and implemented.

Major mental health reform programs will require the identification, prioritisation, sequencing, targeting and monitoring of multiple interdependent initiatives. Single purpose models that assume static systems may be inadequate for the decision support needs of policymakers and service planners [27]. Currently, mental health economic models predominantly address issues relating to the affordability and value for money of individual programs [28] with mental health simulation studies rarely modelling complex systems [29]. Greater use of dynamic systems modelling approaches could provide new insights about inter-dependencies between candidate policies and the evolution of the mental health systems planning context [30]. These types of models might also be the basis for developing reference models [31] of mental health systems that are intended for multiple-applications and re-use by different modelling teams. However, as they are intended for multiple-purposes and because propagation errors may be more likely with more complex models [32] such models require greater investments in model transparency and validation [11,14].

The development, validation and maintenance of these more complex models may be simply too onerous a burden for a single modelling team. Developing networks of modellers working on common health conditions [13] and collaborations across multiple modelling teams that include the ability to re-use and extend each others work, can make complex modelling projects more tractable [33]. Similarly, more attention to developing partnerships between modellers and decision-makers across the life-cycle of a modelling project can help ensure models are appropriately conceptualised and implemented and improve their practical utility as decision aids [34].

Modelling projects should be resourced to be routinely updated and refined as new evidence emerges and decision contexts change [35]. There are significant deficits in our understanding of the systems in which mental disorder emerges and is treated [36] and longer term project horizons could allow mental health models to progressively improve validity as these gaps are addressed. Currently, the theoretical basis for understanding complex mental health systems is weak [37]. Strikingly, it remains unclear why increased investments in mental health care have yet to discernibly reduce the prevalence and burden of mental disorders[38]. The literature about how the requirements, characteristics and performance of mental health services are shaped by spatiotemporal context is underdeveloped [39]. There is insufficient evidence to identify the social determinants of mental disorders most amenable to preventative interventions, and for which population sub-groups such interventions would be most effective [40].

Open source frameworks have been previously recommended for the development of mental health modelling field [29] but, as with health economics more generally, OSHEMs remain rare. Currently there is only one mental health related model (in Alcohol Use Disorder [41]) that is indexed in the Open Source Models Clearinghouse [9,42]. A Major Depressive Disorder reference model for the United States [43] is also being developed as part of the Open Value Initiative [44]. We believe greater support for open source approaches have the potential to provide more transparent, collaborative and sustained approaches to mental health system model development.

2.2 readyforwhatsnext

We are currently developing an open source model of the systems shaping the mental health of young people in Victoria, Australia. The model is called readyforwhatsnext and development progress is reported on a project website [45]. The project aims to produce a reference model that can examine multiple potential population level strategies for prevention (in 0-25 year olds) and treatment (in 12-25 year olds) of mental disorders.

Our approach to model development is to undertake a number of discrete modelling projects and progressively link them together by means of a common framework. Sub-projects we are currently engaged in include those to develop models of people (synthetic populations of interest describing relevant individual characteristics and their household relationships, choice models for predicting helpseeking behaviour and models to map psychological measures to health utility), places (synthesising geometry and spatial attribute data to characterise the geographic distribution of relevant demographic, environmental, epidemiological and service infrastructure features) and platforms (representing the processes and operations of a complex primary youth mental health service). We have also previously undertaken scoping work reviewing economic evidence relating to youth mental health programs [46] and plan to integrate this with the model at a future date.

3 Framework

The framework we have developed consists of a set of standards for OSHEMs and tools for implementing those standards.

3.1 Standards

We have identified 20 standards that we believe are important for quality implementations of OSHEMs, each described under one of following six principles for making models TIMELY:

- **Transparent:** people can easily see how a model has been implemented and tested;
- **Iterative:** a model is routinely updated to maintain and improve validity;
- **Modular:** models and their components can be combined to extend their scope;
- **Epitomized:** models can be used in multiple decision contexts;
- **Licensed:** a model and its derivatives are persistently re-usable by other modellers; and
- **Yielding:** a model can be deployed as a simple, flexible and reliable decision aid.

3.1.1 Transparent Models

A range of tools and practices are available to help make model code and data accessible, citable and comprehensible. The most efficient way to widely disseminate code and data may be to use existing open science infrastructure [1]. Repositories such as Zenodo [16] and Dataverse [47] provide persistent storage solutions that generate a Digital Object Identifier (DOI) for each unique item. These repositories are a

preferable solution for sharing citable code and data than transitory repositories such as corporate websites or GitHub where items can be deleted or relocated at any time [48]. Zenodo includes tools that automate integration with GitHub, which makes it easy for developers to maintain parallel code repositories - one for disseminating the most up to date development code and the other for archiving citable code releases.

Model code and data also need to be clearly documented, potentially with different versions for technical and non-technical users [14]. Developers storing data in a Dataverse installation have access to multiple meta-data fields to document both a data collection and its constituent individual files. In R, code manuals and websites can be created with the aid of tools such as devtools [49], sinew [50], roxygen2 [51] and pkgdown [52].

Consistent use of meaningful naming conventions when authoring code is recommended [18,53]. The main logic of a program can be made comprehensible to even non-technical users though the use of the common practices of abstraction [54], where only simple, high level commands are routinely exposed to reviewers, and polymorphism [55], where the same command (e.g. “simulate”) can be reused to implement different algorithms of the same broad type. Literate programming, where tools like RMarkdown [56] are used to render documents that integrate computer code with plain English descriptions of each step in an analysis workflow, can make code easier to follow by both technical and non-technical users.

An essential component of quality assuring health economic models is verification - ensuring that calculations are correct and consistent with model specifications [57]. One useful concept for informing model users about the extensiveness of verification checks is code coverage [58] - the proportion of model code that has been explicitly tested. In R, the testthat [59] and covr [60] tools can be used in conjunction with GitHub to define tests and report coverage metrics.

Finally, transcription errors - mistakes introduced when transferring data between sources, models and reports - are very common in health economic models [2]. The risk of these errors might be lower if there was full transparency across all steps in a study workflow. Scientific computing tools now make it relatively straightforward to author programs that reproducibly execute all steps in data ingest, processing and reporting [53].

Standards:

- **T1: Uniquely identified copies of model code and data are permanently archived in open online repositories**
- **T2: Model code and data are documented**
- **T3: Model code uses a simple and consistent syntax**
- **T4: Model analyses and reporting are implemented using literate programming**
- **T5: Code coverage is reported**
- **T6: All parts of a study analysis and reporting workflow can be reproduced and/or replicated**

3.1.2 Iterative Models

To avoid OSHEMs going stale - losing validity and usefulness with time - they should be routinely updated. A number of tools and approaches can make the process of implementing and curating changes to model code and data more coherent and efficient. Repositories such as Zenodo [16] and Dataverse [47] provide persistent access to all published versions of a dataset, each uniquely identifiable. For code, use of version control tools like Git [17] can ensure that the entire development history of a project is organised so that each version is distinguishable and retrievable by developers. The online platform GitHub [15] can make this version history accessible to anyone.

Adopting semantic versioning [61] conventions can be an efficient way to provide users of model code and data with information about the potential importance of an update. For R code, the `usethis` [62] package can be used to partially automate version number increments using the convention `Major.Minor.Patch.Development`. Datasets stored on the Harvard Dataverse use the simpler `Major.Minor` convention.

Continuous integration [63] tools can help verify that each code update passes multiple quality tests. OS-HEMs developed in R can take advantage of templates provided by `devtools` [49] and `pkgdown` [52] to run continuous integration checks on GitHub. These tests can include those of units (do individual functions produce expected output?), documentation (does documentation render correctly?, can all example workflows be executed?) and installation (can the software be successfully deployed on multiple types of operating system?).

Finally, using deprecation conventions that take an informative and staged approach to retiring old code and data reduces the risk that model revisions have unintended consequences on third party users. The package lifecycle [64] provides tools for R developers to consistently deprecate their code.

Standards:

- **I1: Model code is version controlled**
- **I2: Model code and data use semantic versioning**
- **I3: Continuous integration is used to verify model code updates**
- **I4: Deprecation conventions are used to retire model code and data**

3.1.3 Modular Models

Modular health economic models link multiple self-contained components that are independently reusable and extendable for other projects [65,66].

Many types of mental health data are highly sensitive with strict confidentiality requirements. For this reason, not all data included in some mental health models can be made widely available for others to re-use. A modular approach that ensures that model code and data are decoupled (stored in different files) can help model developers to restrict access to confidential model data, while providing open access to all other model components.

A key challenge when developing modular models is to ensure that the integrity of each self contained component (or module) is protected when interacting with others. The coding practice of encapsulation [54] can help ensure that model modules can be safely combined [ready4oop2022].

Standards:

- **M1: Model code and data are stored and managed separately**
- **M2: Model code defines encapsulating data structures**

3.1.4 Epitomised Models

Modular code is also recommended as good practice for scientific computing more generally [53].

[model functions - compare to analysis and reporting]

Standards:

- **E1: Model code is distributed as libraries of functions**
- **E2: Model code defines inheriting data-structures**
- **E3: Test data is available to demonstrate generalised model applications**

3.1.5 Licensed Models

copyleft licensing [67] is used to ensure that Standards:

- **L1:** Model code is made available for re-use under copyleft licenses
- **L2:** Non-confidential model data is available for liberal re-use, subject to adherence clearly specified ethical standards
- **L3:** Model code and data are distributed with citation tools

3.1.6 Yielding Models

Shiny tutorial [68]

- **Y1:** Non- technical users can configure and run models via simple user-interfaces
- **Y2:** Statistical models can be safely, consistently and flexibly deployed using standardised tools

3.2 Toolkits

3.2.1 Technical platforms

3.2.2 Software Development Kit

4 Application

Worked example

5 Discussion

MH systems design is not a pharma led project - less concerns about commercial ownership
greater use of these types of models may require adaptation on the part of funders, modellers and decision-makers. T

Availability of data and materials

Ethics approval

Details on ethics approvals go here.

Funding

The study was funded by Orygen, VicHealth and Victoria University.

Conflict of Interest

None declared.

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A Appendix