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 addressing issues relating to the affordability and value for money of individual programs [28] with mental health simulation studies rarely modelling complex systems [29]. Dynamic systems modelling approaches can provide insights about inter-dependencies between candidate policies and the evolution of the mental health systems planning context [30]. These types of models could be the basis for developing reference models [31] intended for multiple-applications and re-use by multiple 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]. Sustained long term funding is required for mental health projects to remain current and to enable the mental health modelling field address a number of key challenges. There are significant gaps in our understanding of the systems in which mental disorder emerges and is treated [36] and 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 and tools for implementing those standards.

3.1 Standards

We have identified 15 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 fix errors, incorporate new data and improve performance;
- Modular: multiple models and their components can be readily combined to explore topics of more extensive scope;
- Epitomized: model code is sufficiently generalised to be applied or adapted to other contexts and decision problems;
- Licensed: a model's constituent parts and derivative works are persistently re-usable by other modellers; and
- Yielding: a model can be deployed as a flexible and easy to use decision aid.

3.1.1 Transparent Models

Transparency can be facilitated by making model code and data accessible, citable, clear and complete. The most efficient way to make model code and data widely accessible may be to use existing open science infrastructure [1]. Repositories such as Zenodo [16] and Dataverse [47] provide persistent storage of code and data and 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 which can be deleted or relocated at any time [48]. Zenodo includes tools that automate integration with GitHub, which makes ieasy for developers to maintain parallel code repositories - one for disseminating the most up to date in development code and the other for archived 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 the dataset as a whole and individual files contained by that dataset. In R, code libraries can be documented with the aid of tools such as devtools [49], sinew [50] and roxygen2 [**roxygen22021?**] that create manuals that conform to a standardised template, and pkgdown [51] for creating package websites.

Code can be made easier to follow through a number of development choices. For technical users, use of a consistent and explicit house-style can make it easier to review large bodies of code. The high level logic of a program can be made more comprehensible for non-technical users though the use of abstraction, that routinely exposes only simple, top level commands. Polymorphsim, where the same high level command (e.g. "simulate") can implement multiple different lower level algorithms of the same broad category of task, can further simplify code. Literate programming, where computer code is integrated with plain English descriptions of each main step in an analysis workflow, can make code easier for review by both technical and non-technical users.

Finally, transcription errors - mistakes introduced when transferring data between data 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 make it feasible to author programs that reproducibly execute all steps from raw data ingest through data processing, analysis, rendering of a scientific manuscript and dissemination of study outputs in online repositories.

Standards:

- T1: Permanent, uniquely identified archived copies of model code and data are publicly available in open access online repositories

- T2: Models and their code and data are clearly and consistently documented
- T3: Model logic is easy to follow through use of a simple and consistent syntax [abstraction and polymorphism, house style]
- T4: Model analyses and reporting are implemented using a literate programming approach

- T5: All parts of a study workflow from raw data ingest through to dissemination of study outputs can be reproduced and/or replicated by third parties using publicly available materials.

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.

GitHub also provides continuous integration [52] tools that can help make code updates more reliable. OSHEM developed in R can take advantage of templates provided by devtools [49] and pkgdown [51] to run

GitHub continuous integration checks that each new version of a code library passes multiple quality tests. 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?).

Adopting semantic versioning [53] 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 [54] 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. Finally, using deprecation conventions that take an informative and staged approach to retiring old code and data can reduce the risk that model revisions have unintended consequences on third party users. The package lifeycle [55] provides tools for R developers to consistently deprecate their code.

Standards:

I2: Model code is version controlled

I3: Model code development uses continuous integration (CI) tools and test units to ensure each new version is quality assured

I1: Model code and data use semantic versioning

I4: Deprecation conventions are used to retire old code / data in order to minimise the risk of unintended impacts on downstream dependencies

3.1.3 Modular Models

M1: Model code and data are decoupled – each is stored, managed, licensed, disseminated and cited independently

M3: Model code defines encapsulating data structures [that can be safely combined].

3.1.4 Epitomised Models

M2: Model code is distributed as code-libraries [compare to analysis and reporting]

E2: Model code defines inheriting data-structures.

E1: Model code deploys a combination of object oriented and functional programming.

3.1.5 Licensed Models

copyleft licensing [56] is used to ensure that L1: Model code and data are available for viewing and re-use in open access online repositories under copyleft licensing arrangements.

3.1.6 Yielding Models

Shiny tutorial [57] Y1: Non- technical users can configure and run models via simple user-interfaces

3.2 Toolkits

3.2.1 Technical platforms

3.2.2 Software Development Kit

3.3 Application

Worked example

4 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.

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Conflict of Interest

None declared.

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A Appendix