Advances at the intersection of health economics & data science

Robert Smith
Dark Peak Analytics & University of Sheffield

R-LMIC, 20 January 2023

Structure

1. **Background**

2. **Two papers**: Outline two related advancements in health economics:

   a. Making Health Economics Shiny to improve model transparency & usability

      Smith, R.A., and **Schneider, P.P.** (2020). Making health economic models Shiny: A tutorial. *Wellcome Open Res*, 5, 69. https://doi.org/10.12688/wellcomeopenres.15807.2

   b. Living HTA: is automating health economic evaluation updates feasible.

      Smith, R.A., Schneider, P.P., and **Mohammed, W.** (2022). Living HTA: Automating Health Economic Evaluation with R. *Wellcome Open Res*, 7, 194. https://doi.org/10.12688/wellcomeopenres.17933.2

      Thokala, P., Srivastava, T., **Smith, R.**, Ren, S., Whittington, M.D., Elvidge, J., Wong, R., Uttley, L. (2023). Living Health Technology Assessment – Issues, Challenges and Opportunities. *Pharmacoeconomics* [In Press]

3. **Question and answer**: Relevance to LMIC

Who we are ...

Dr Paul Schneider

Robert Smith

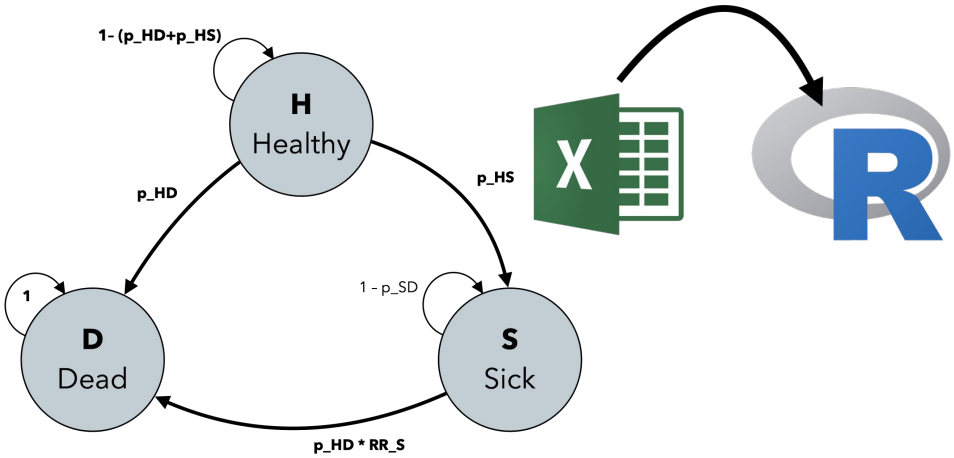
Dr Sarah Bates

ShangShang Gu

Wael Mohammed

What we do...

1 Health economic decision modelling
+ Model review
+ User interfaces
+ MS Excel → R

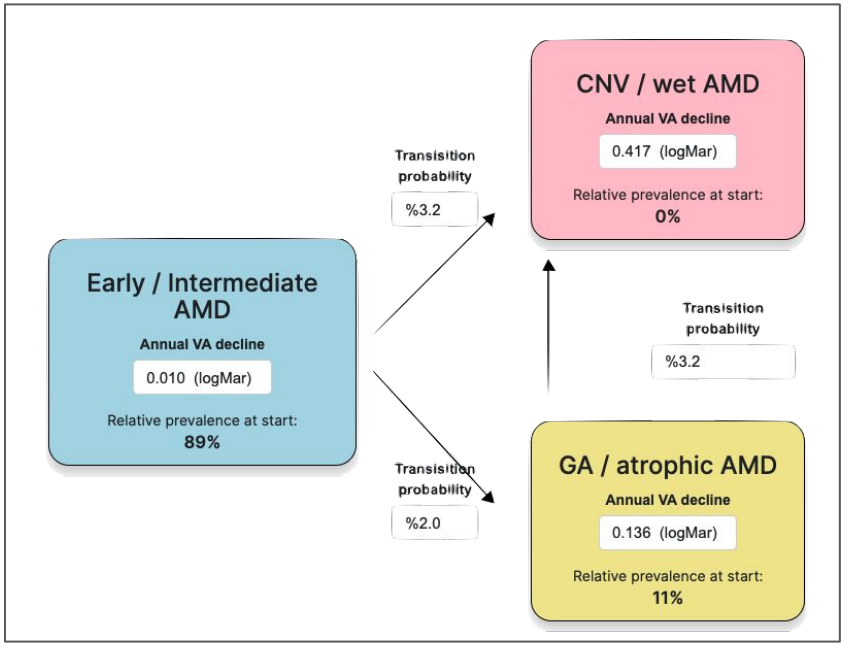


2 Training + workshops
+ tailored content
+ Hands-on exercises
+ Expert guidance

What we do... modelling

Building health economic and epidemiological models in R

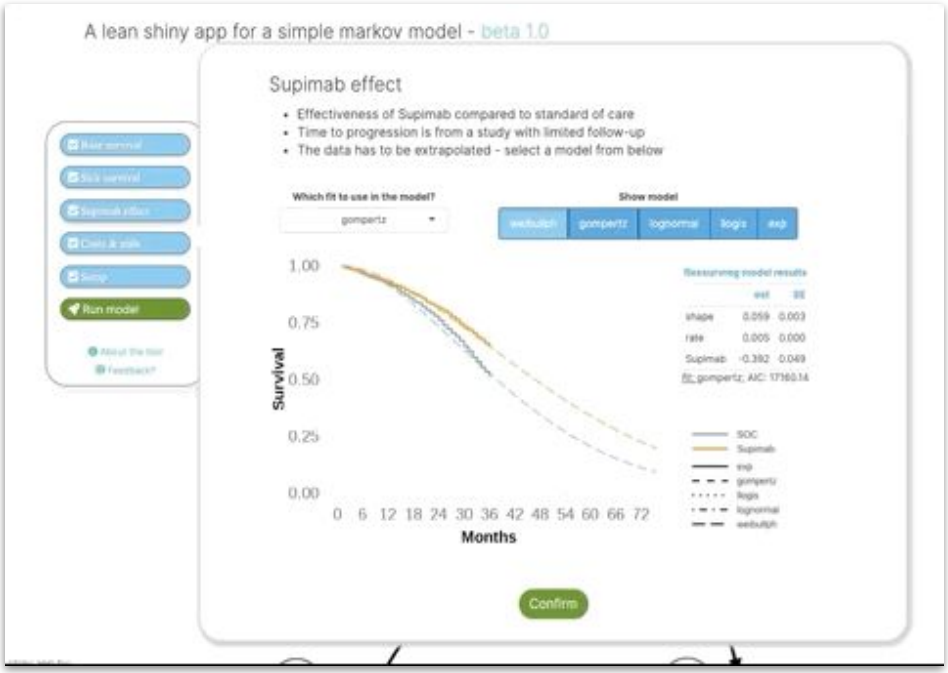
+ Creating a self-contained software package with in-built unit testing
+ Including documentation and version control
+ Developing software to help build health economic models for public health



What we do... user interfaces

Interactive user interfaces to increase accessibility and engagement

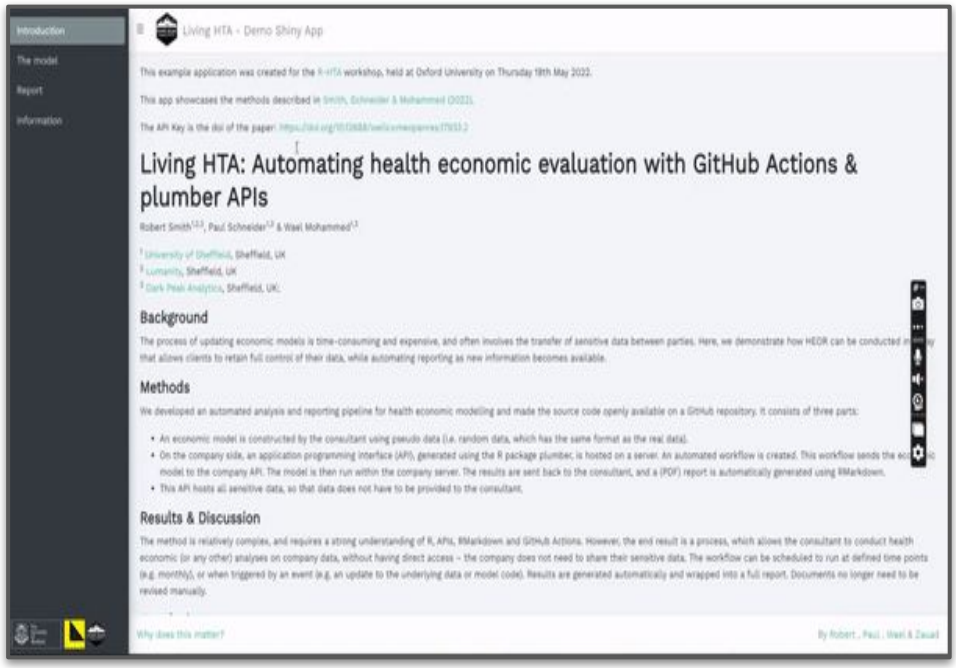
+ Creating interactive user-interfaces for health economic models written in R/C++.
+ We work in short sprints in close collaboration with you to develop interfaces that are intuitive and easy for your target audience to understand and use.



What we do... data science

Solutions from data-science, applied to HTA.

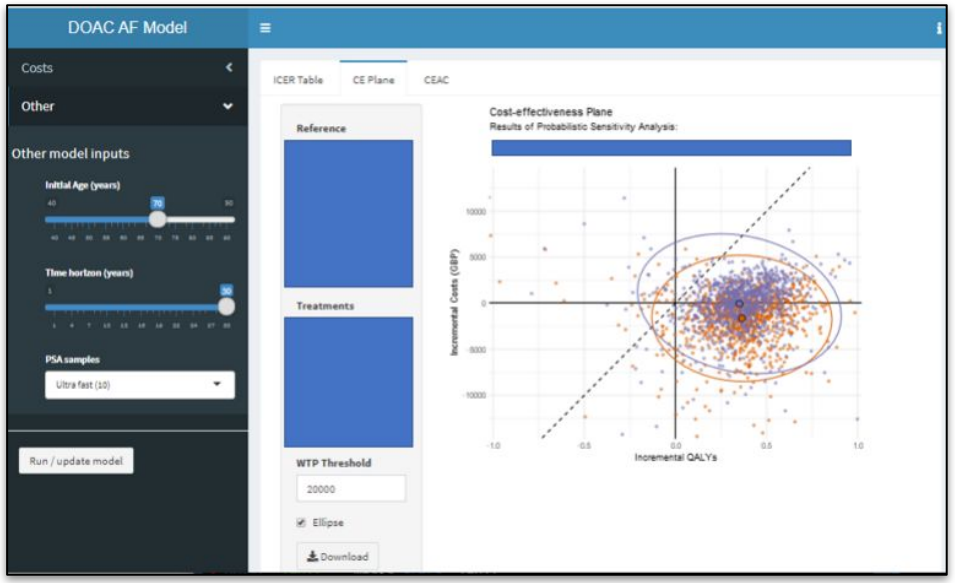
+ Sending a health economic model to the data, negating the need for sensitive data to be shared externally.
+ Model updates can be automated as RWE changes.



What we do... model review

In depth review of health economic models

+ We specialise in reviewing models written in R
+ We use automated testing to identify bugs and errors
+ building UIs allows non-programmers to test and query models written in R.



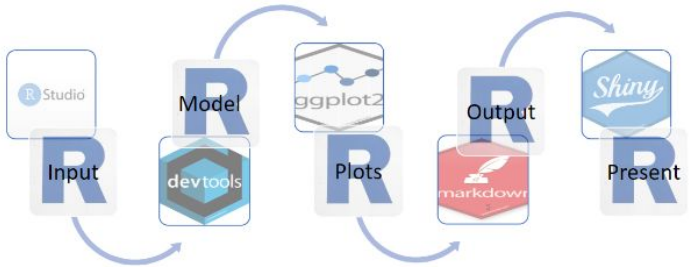
Case Study: Identified bug in ERG code and ran sensitivity analysis to identify most influential parameters. Developed an optimal pricing algorithm to help inform negotiations. Most importantly, built app to allow client to play with the model and investigate effect of using updated evidence in the model. As a result the ERG model was improved and a more favourable outcome achieved for our client.

What we do... teaching

8 Automated Reporting

8.1 Background

One of the benefits of building models in R is that we can write code to generate reports based on the inputs and outputs of our model. This was a crucial part of our proposed transition of the health economic evaluation pipeline towards something that looks like this:



New pipeline

This section guides the reader through the process of writing such a report using two R packages, `Rmarkdown` (for a PDF document) and `officeR` (for a Powerpoint presentation). Both packages are able to output in a large number of formats.

We show how to write these reports in such a way to be functional and aesthetically pleasing, and show how to write a single script which runs a health economic model and then renders a PDF or set of Powerpoint slides using the parameters and results of

What we do... open research

Wellcome Open Research

Wellcome Open Research 2020, 5:69 Last updated: 05 JUL 2022

Check for updates

METHOD ARTICLE

REVISED Making health economic models Shiny: A tutorial [version 2; peer review: 2 approved]

Robert A. Smith*, Paul Schneider*

School of Health and Related Research, University of Sheffield, Regents Court, Sheffield, S1 4DA, UK

* Equal contributors

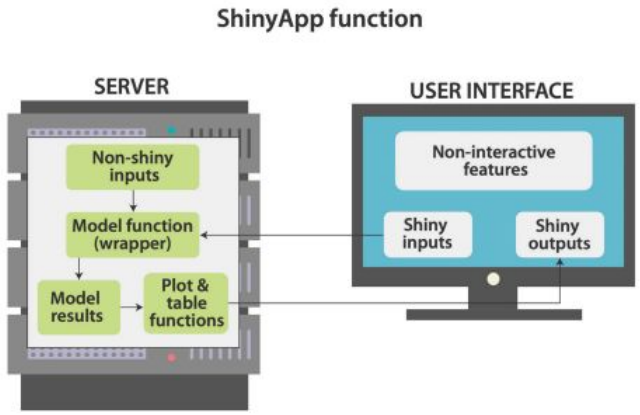


Figure 1. Diagram depicting how the Sick-Sicker app is structured.

Smith RA and **Schneider PP.** Making health economic models Shiny: A tutorial. *Wellcome Open Res* 2020, **5**:69 (https://doi.org/10.12688/wellcomeopenres.15807.2)

Wellcome Open Research

Wellcome Open Research 2022, 7:194 Last updated: 24 OCT 2022

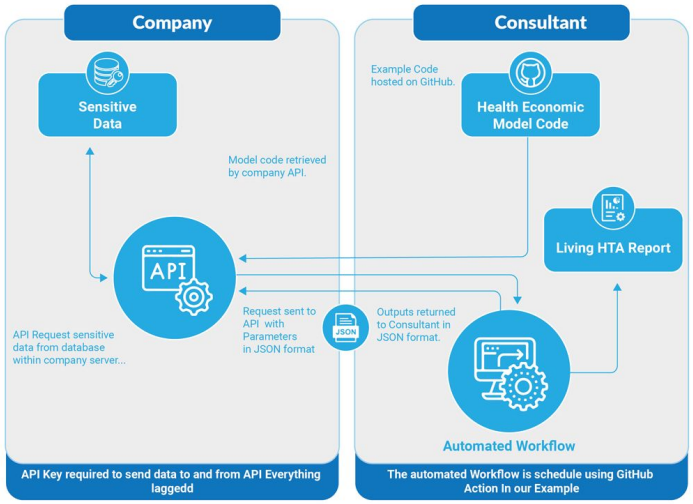
Check for updates

METHOD ARTICLE

REVISED Living HTA: Automating Health Economic Evaluation with R [version 2; peer review: 2 approved]

Robert A. Smith[1-3], Paul P. Schneider[1,3], Wael Mohammed[1,3]

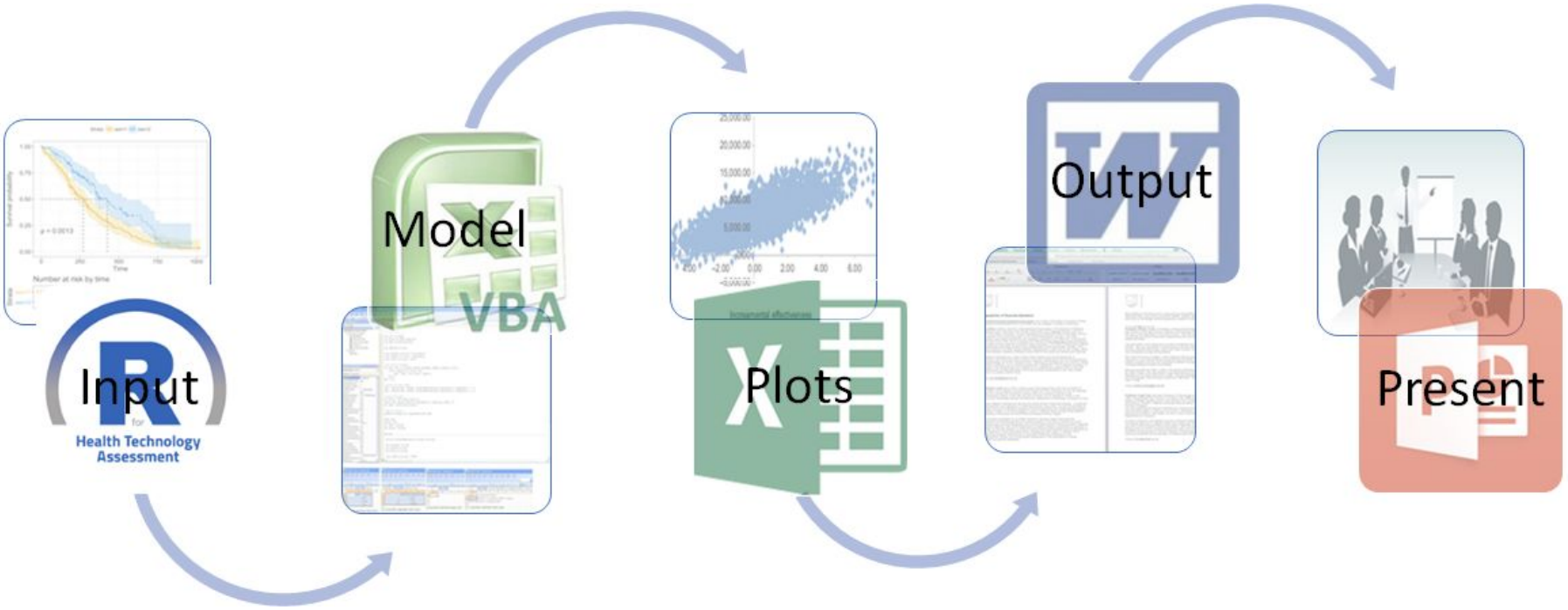
[1]School of Health and Related Research, University of Sheffield, Sheffield, S1 4DA, UK
[2]Lumanity, Sheffield, S1 2GQ, UK
[3]Dark Peak Analytics, Sheffield, S11 7BA, UK



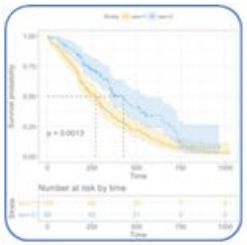
Smith RA, Schneider PP and **Mohammed W**. Living HTA: Automating Health Economic Evaluation with R. *Wellcome Open Res* 2022, **7**:194 (https://doi.org/10.12688/wellcomeopenres.17933.2)

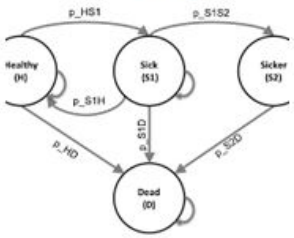
User-interfaces with shiny

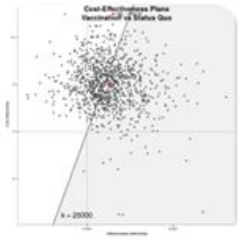
Current process



Future process







Simple app

Sick Sicker Model in Shiny

Treatment Cost

200

PSA runs

1000

initial age

10 25 80

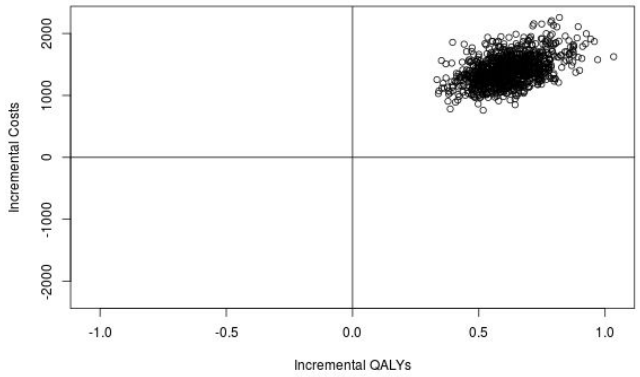
10 17 24 31 38 45 52 59 66 73 80

Run / update model

Results Table

Option	QALYs	Costs	Inc.QALYs	Inc.Costs	ICER
Treatment	18.59	100441.67	0.62	1406.24	2324.54
No Treatment	17.97	99035.43	NA	NA	NA

Cost-effectiveness Plane



https://robertasmith.shinyapps.io/sick_sicker

Open-source tutorial

Inputs → Function → Outputs

Parameters		
c_s1	cost1	3
c_s2	cost2	5
c_H	cost3	6
dr	Dis_rate	0.035
n_sim	No. psa	1000

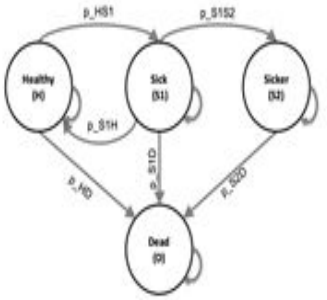
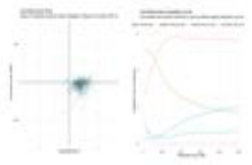


Figure 1: State-transition diagram of the time-independent Sick-Sicker cohort state-transition model with the name of the health states and possible transitions with their corresponding transition probabilities.

Results Table

Option	QALYs	Costs	Inc.QALYs	Inc.Costs	ICER
Treatment	18.56	101106.37	0.63	1422.23	2320.60
No Treatment	17.93	99684.14	NA	NA	NA



Open-source tutorial

Inputs → Function → Outputs

Parameters		
c_s1	cost1	3
c_s2	cost2	5
c_H	cost3	6
dr	Dis_rate	0.035
n_sim	No. psa	1000

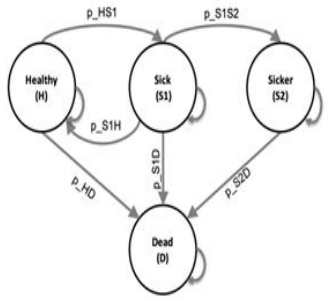
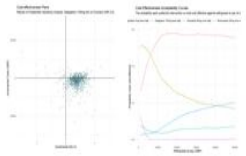


Figure 1: State-transition diagram of the time-independent Sick-Sicker cohort state-transition model with the name of the health states and possible transitions with their corresponding transition probabilities.

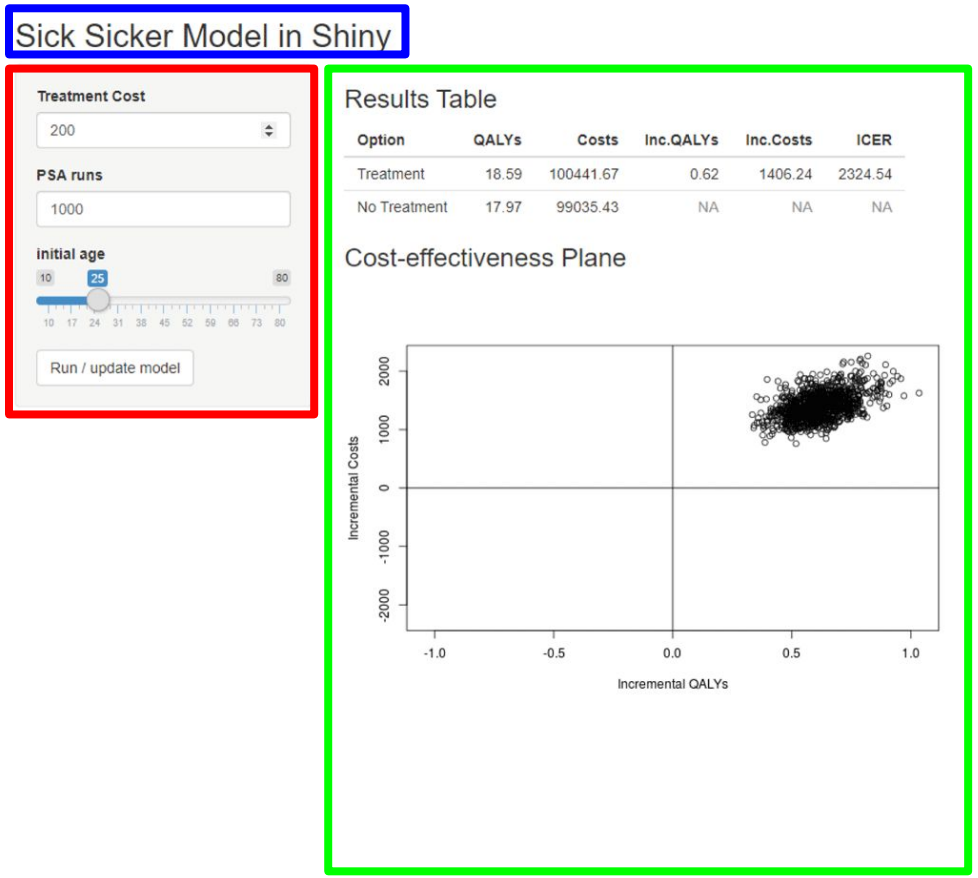
Results Table

Option	QALYs	Costs	Inc.QALYs	Inc.Costs	ICER
Treatment	18.56	101106.37	0.63	1422.23	2320.60
No Treatment	17.93	99684.14	NA	NA	NA



UI code

```
ui <- fluidPage (     # creates empty page

  # title of app
  titlePanel("Sick Sicker Model in Shiny"),

   # layout is a sidebar-layout
   sidebarLayout(

  # open sidebar panel

      < SIDEBAR PANEL CODE >

# open main panel

      < MAIN PANEL CODE >

         )# close sidebarlayout

) # close UI fluidpage
```



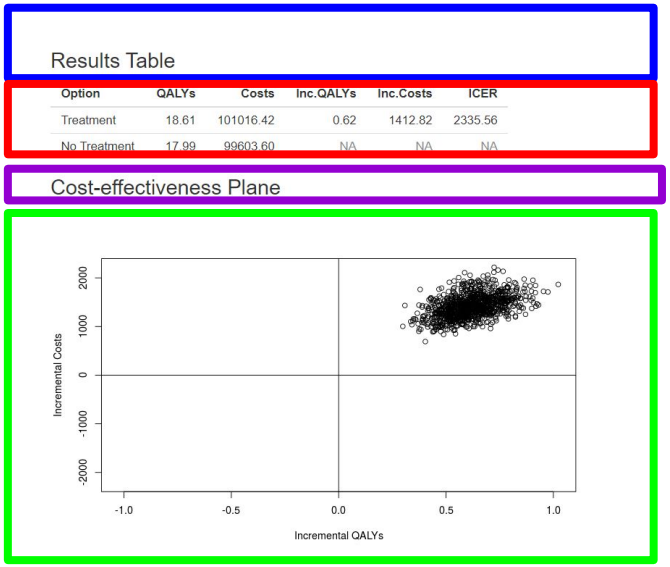
https://r-hta.org/tutorial/markov_models_shiny/

Sidebar Panel Code

```
sidebarPanel( # open sidebar panel
    numericInput(inputId = "SI_c_Trt",
                 label = "Treatment Cost",
                 value = 200,
                 min = 0,
                 max = 400),
    numericInput(inputId = "SI_n_sim",
                 label = "PSA runs",
                 value = 1000,
                 min = 0,
                 max = 400),
    sliderInput(inputId = "SI_n_age_init",
                label = "Initial Age",
                value = 25,
                min = 10,
                max = 80),
    # action button runs model when pressed
    actionButton(inputId = "run_model",
                 label   = "Run model")
 )  # close sidebarPanel
```

Main Panel Code

```
mainPanel(

# heading (results table)
    h3("Results Table"),

# tableOutput id = icer_table, from server
    tableOutput(outputId = "SO_icer_table"),

# heading (Cost effectiveness plane)
    h3("Cost-effectiveness Plane"),

# plotOutput id = SO_CE_plane, from server
    plotOutput(outputId = "SO_CE_plane")

            ) # close mainpanel
```



Server Code

```
server <- function(input, output){

 observeEvent(input$run_model,  # WHEN ACTION BUTTON PRESSED
              ignoreNULL = F, {

# Run  model function with Shiny inputs
 df_model_res = f_wrapper(c_Trt = input$SI_c_Trt,
                          n_age_init = input$SI_n_age_init,
                          n_sim = input$SI_n_sim)

#-- CREATE COST EFFECTIVENESS TABLE --#
# renderTable continuously updates table
 output$SO_icer_table <- renderTable({

 < ICER TABLE FUNCTION >

 }) # table plot end.

 #-- CREATE COST EFFECTIVENESS PLANE --#
 # render plot repeatedly updates.
 output$SO_CE_plane <- renderPlot({

 < CE PLANE FUNCTION >

 }) # renderplot end

 }) # Observe event end

 } # Server end
```

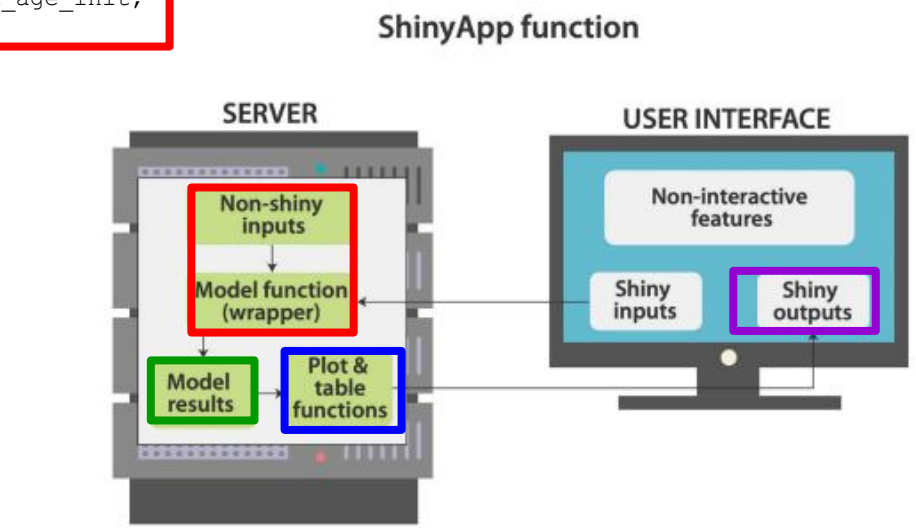


Figure 1. Diagram depicting how the Sick-Sicker app is structured.

More sophisticated app

https://darkpeakanalytics.shinyapps.io/sadm-mk2/

Distracting bling

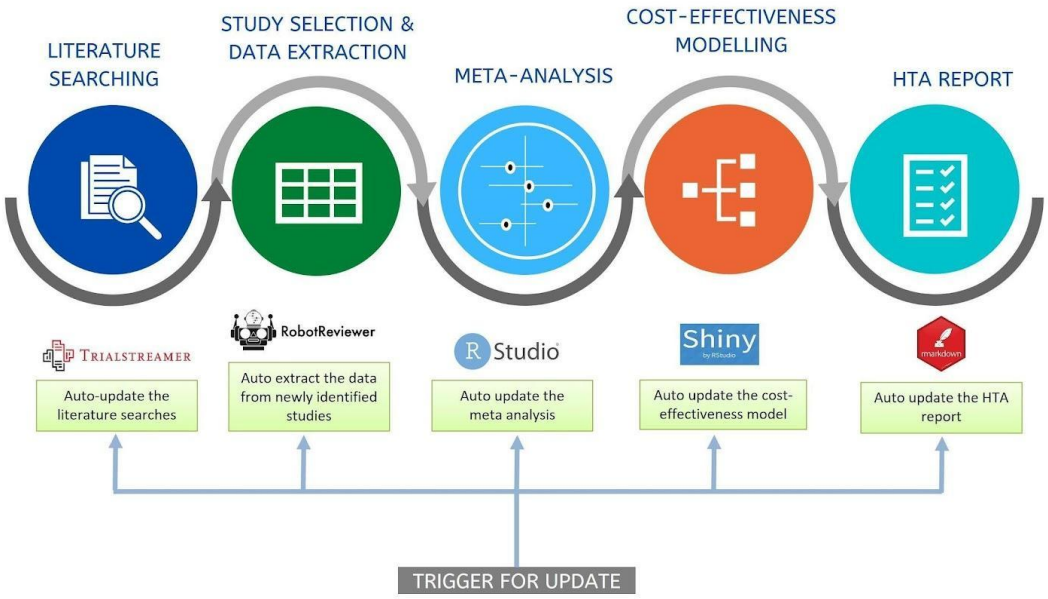
Shiny is like a superhero costume for R-based health economic models, it gives them a flashy makeover and makes them more presentable to the decision maker. But a fancy app does not substitute for a well constructed model .

R Smith (2023)

Living HTA with plumber

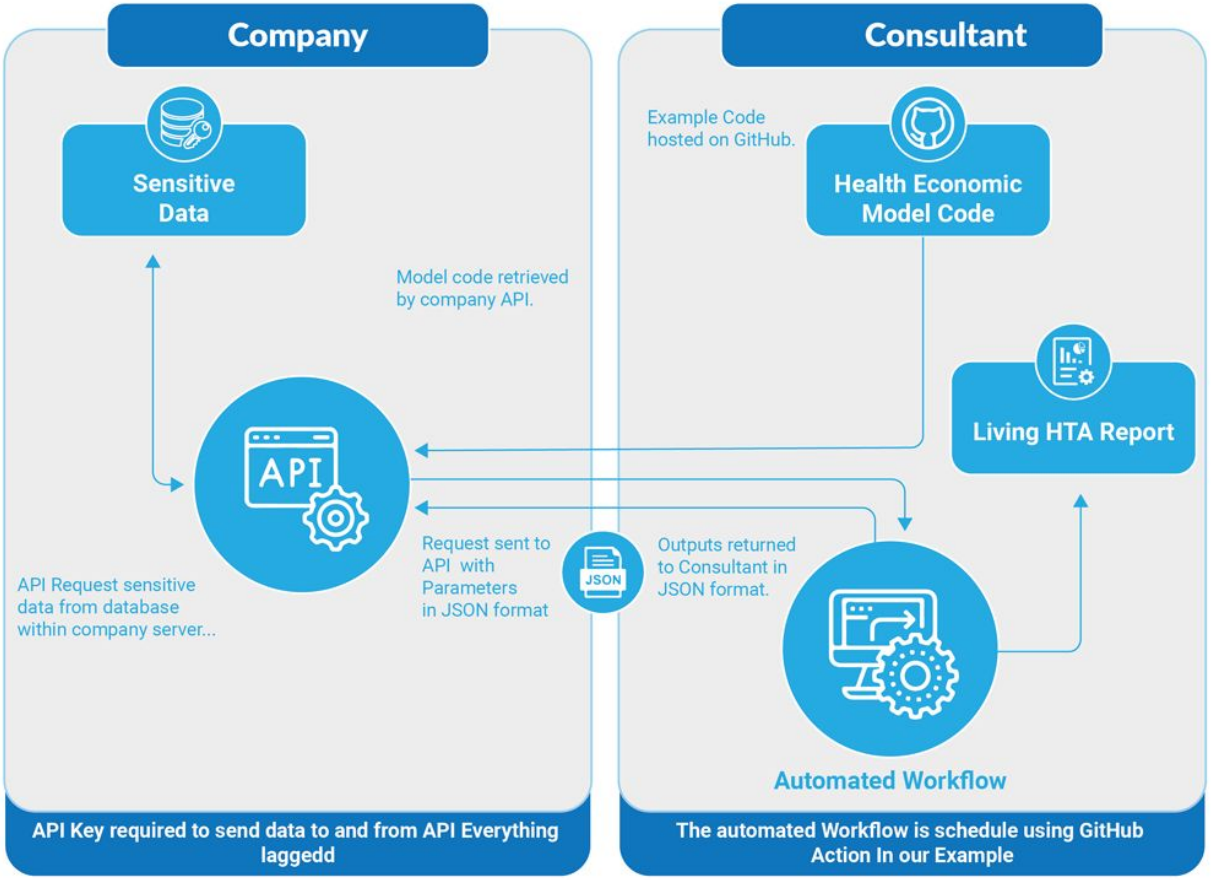
Living HTA

Figure 3: Potential example living HTA using (semi-)automation

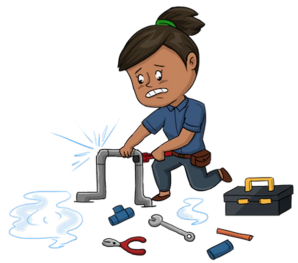


Thokala, P., Srivastava, T., **Smith, R.**, Ren, S., Whittington, M.D., Elvidge, J., Wong, R., Uttley, L. (2023). Living Health Technology Assessment – Issues, Challenges and Opportunities. *Pharmacoeconomics* [In Press].

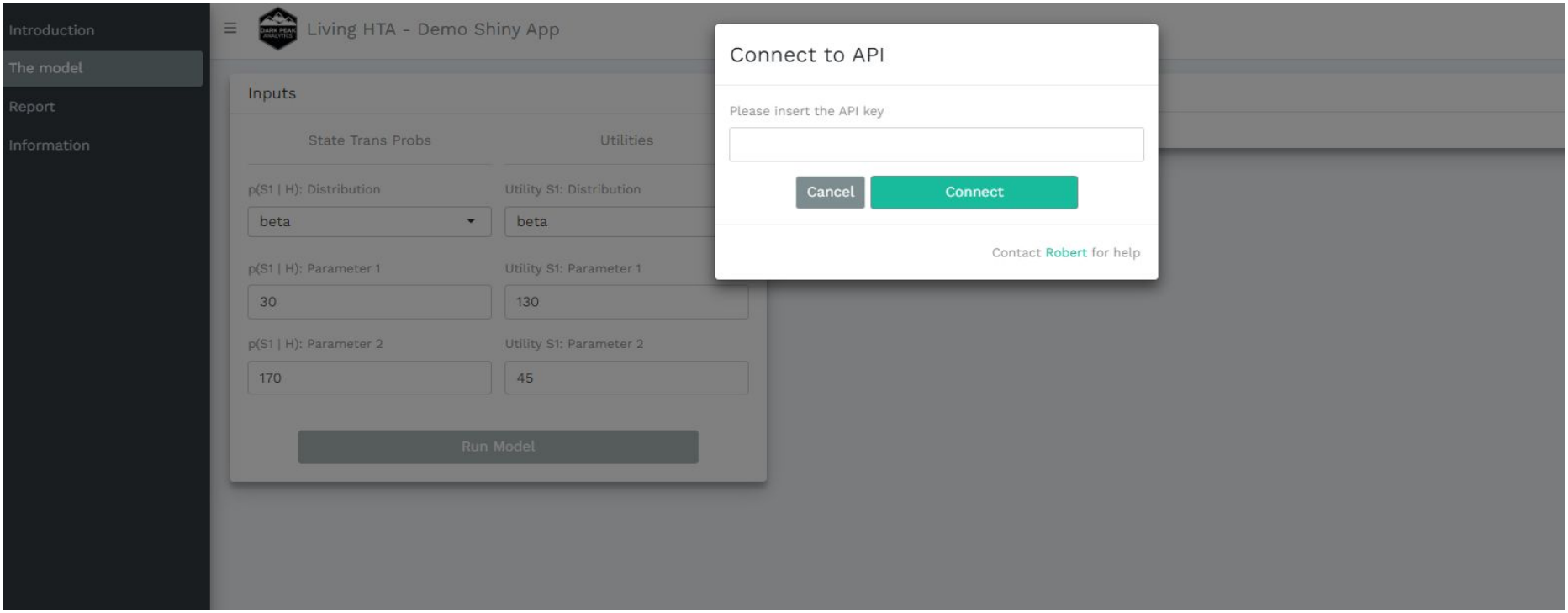
Living HTA App Demo



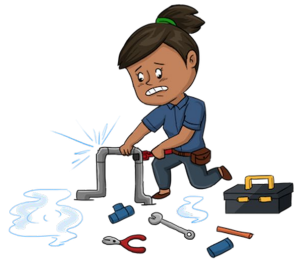
https://darkpeakanalytics.shinyapps.io/living_HTA_demo/



Living HTA App Demo



https://darkpeakanalytics.shinyapps.io/living_HTA_demo/



Who can access what?

Agent	Sensitive Data	Model code	Other data
Data Owner (Pharmaceutical company)	☑	☑	☑
External Consultant (Health Economist)	x	☑	☑
3rd Party Consultant (App designer)	x	x	☑

Advantages

Security - Data owners retain control of their data. No data need leave the data-owner's servers.

Transparency - Separating the model code from the data can significantly improve the transparency of the health economic model. Many models could be passed to the data, not just one!

Computational Power - The computational burden of the model is handled on a remote server.

Storage – Larger datasets can be analyzed than would be possible on a laptop.

Living analysis - API calls can be made at any time. A decision maker can see a report that will always reflect the data held by the company.

Disadvantages

Security - Likely to remain concerns about data security, even with the authentication procedures built into the API functionality.

Transparency - Risk that running the model remotely will result in the perception that the model is a 'black box' (I'd disagree!).

Coding practice - The model code needs to be versatile enough to manage unknown data updates. *Proper testing will help mitigate these risks.*

Technical skillset - This is not commonly implemented, or a common skill-set among health economists. Most models are not built in R.

Resistance to Change

Iterating

Further resources

Smith, R.A., Schneider, P.P., and **Mohammed, W.** (2022). Living HTA: Automating Health Economic Evaluation with R. *Wellcome Open Res*, 7, 194. https://doi.org/10.12688/wellcomeopenres.17933.2

Smith, R.A., and **Schneider, P.P.** (2020). Making health economic models Shiny: A tutorial. *Wellcome Open Res*, 5, 69. https://doi.org/10.12688/wellcomeopenres.15807.2

Thokala, P., Srivastava, T., **Smith, R.**, Ren, S., Whittington, M.D., Elvidge, J., Wong, R., Uttley, L. (2023). Living Health Technology Assessment – Issues, Challenges and Opportunities. *Pharmacoeconomics* [In Press].

Open Source code for Shiny: https://github.com/RobertASmith/healthecon_shiny
Open Source code for Living HTA: https://github.com/RobertASmith/plumberHE

Living HTA slides: Earl Conference London 2022
Living HTA talk (25 mins): EARL Conference London 2022

Dark Peak Analytics

https://www.linkedin.com/in/robert-smith-53b28438/
www.darkpeakanalytics.com
www.github.com/dark-peak-analytics