Final Report: Stakeholder perceptions of and options for
refining the CEBRA 'Value' model for use within DAWE.

CEBRA Project 20100401

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# **Abbreviations**

ABARES Australian Bureau of Agricultural and Resource Economics and Sciences

CBIS Compliance Based Inspection Scheme

CEBRA Centre of Excellence for Biosecurity Risk Analysis

DAWE Department of Agriculture, Water and the Environment

ISPM International Standard for Phytosanitary Measures

FMD Foot and Mouth Disease

MDAP Melbourne Data Analytics Platform

MPI Ministry for Primary Industries

OCEBO Office of the Chief Environmental Biosecurity Officer

OCPPO Office of the Chief Plant Protection Officer

OCVO Office of the Chief Veterinary Officer

SAC Scientific Advisory Committee

UoM The University of Melbourne

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# **Executive Summary**

- 1. Under the former research and innovation priority of *Strengthening scientific capability*, CEBRA Project 170713 (hereafter, 'the Value project') sought to identify, develop and ultimately implement novel methods for estimating the aggregate impact of exotic pests and diseases on environmental and social sectors, as well as on agriculture, in monetary terms.
- 2. Whilst the primary objective of the Value project was to generate a baseline estimate of the value of the Australian government's biosecurity controls, during its delivery, the project also developed a bespoke modelling framework capable of simulating the arrival, spread and impacts of more than 40 groups of hazards on sixteen different classes of assets over time.
- 3. A model of this kind has an enormous number of potential applications; however, it is not currently clear what the full suite of potential applications are, nor the relative levels of demand for them. Further, the model is currently configured as a research tool rather than as user-friendly software, limiting options for its deployment.
- 4. To this end, CEBRA Project 20100401 (this project) was commissioned with three objectives: first, to socialise the model among key stakeholders across the Department of Agriculture, Water and the Environment (DAWE); second, to understand exactly how these stakeholders see the model assisting their area in its day-to-day operations; and third, to begin the process of refining the model so that it may ultimately be deployed in these contexts.
- 5. Several rounds of engagement were proposed. The initial rounds of engagement were focussed on gathering general feedback supporting the identification of use cases and potential 'quick win' model updates whilst the subsequent rounds were focussed on refining and determining the relative priority of the more substantive proposed improvements.
- 6. In total, 24 hours of engagement was undertaken by the CEBRA project team across 15 separate meetings. These meetings have included 42 representatives from each of the seven divisions (or offices) within the DAWE Biosecurity and Compliance Group, the Portfolio Strategy Division and ABARES.
- 7. These meetings identified some 25 (from a total of 50) unique points of positive feedback, 25 (of 45) points of potential improvement and 18 (of 36) possible use cases. These use cases could be further distilled into generic user stories.
- 8. These user stories were:
  - Enhanced collaboration through a shared understanding of risk;
  - Statutory environmental assessments (e.g., bioregional assessments);
  - Pest risk [consequence] analysis (e.g., national significance assessments);
  - Design of multi-hazard biosecurity risk controls;
  - System optimisation (i.e., prioritisation and/or resourcing of controls); and
  - Ex-post evaluation of system level performance.
- 9. Of the 25 points of potential improvement, ten were suitable for implementation as quickwin model updates. The project sponsor endorsed a workplan to complete seven of the ten quick-wins, over twelve weeks, with the remaining three designated as reserves.
- 10. We describe here the development requirements for each of the remaining seventeen potential improvements; including, where those improvements have been addressed via other projects that have sought to leverage the value model framework (e.g., CEBRA 21D); and conclude with an assessment of the relative priority of the outstanding activities.

# 1 Introduction

As an academic discipline, biosecurity is almost exclusively hazard oriented. That is, the majority of biosecurity analyses are either single hazard x single risk control; single hazard x multiple control or, rarely, multiple hazard x single control focused – despite the objective being to minimise harm on multiple assets and its implementation involving multiple risk controls that jointly or separately target multiple hazards (Dodd et al., 2017; Dodd et al., 2020). In part, this is due to the reductionist nature of science (i.e., seeking to manage the complexity of a system by studying its constituent parts), though, it's also a reflection of the difficulty associated with delivering operationally relevant applied science (Addison et al., 2013; Kompas & Ha, 2019). An example of this is the portrayal of 'prevention' as a risk control (Leung et al., 2002; Finnoff et al., 2007). Prevention is, rather, an outcome that is achieved through the combination of risk controls such as import conditions, container inspection, fumigation, etc., many of which are non-selective when deployed. Consequently, little guidance exists in the literature as to how such combinations of multi-hazard risk controls should be best organised (though, see van Klinken et al., 2020) with most authors treating them as 'black-box' single-hazard controls (see Moore et al., 2010; Rout et al., 2011). This shortfall in theoretical guidance hampers progress in practice as managers are required to span the gap from first principles and rules of thumb in the absence of a broader multi-hazard framework.

# 1.1 The CEBRA 'Value' project

The primary objective of CEBRA Project 170713 (hereafter, 'the Value project') was to generate a baseline estimate of the effectiveness of the Australian government's biosecurity controls at reducing the impacts of pests and diseases on environmental and social sectors, as well as on agriculture, in monetary terms. Given the lack of an existing theoretical framework for evaluating the effectiveness of risk controls that target multiple hazards with inter-dependent impacts, a staged approach was required:

- Phase One (Dodd et al., 2017) delivered a comprehensive review of the biosecurity economics literature, a detailed description of Australia's biosecurity system, four small case studies highlighting critical issues (knowledge gaps) identified by the project team, and an overarching framework for accurately estimating the value of biosecurity 'systems'.
- Phase Two (Stoeckl et al., 2018) delivered a comprehensive review of the non-market valuation literature relevant to biosecurity, developed a detailed framework for extending existing consequence measures to include non-market values, including a method for properly aggregating measures of impact up to the system scale, and prepared two detailed case studies demonstrating proof of concept for a whole-of-system approach.
- Phase Three (Dodd *et al.*, 2020; Stoeckl *et al.*, 2020) implemented our novel whole-of-system approach to valuation. We first compiled estimates of the annual flow of benefits (both market and non-market) arising from sixteen different assets vulnerable to biosecurity hazards, and thus protected by the Australian government's biosecurity controls including the distribution of those assets across space. We then developed a bespoke, spatially explicit, bio-economic simulation model capable of simultaneously modelling the arrival, spread and impact of 40 functional groups of hazards on those sixteen assets, over time.

When paired with estimated rates of pest establishment from the Department of Agriculture, Water and the Environment's Risk Return Resource Allocation (RRRA) model (described in Craik et al., 2017) we were able to use this framework to estimate the future damages that may be avoided due to the implementation of the government's risk controls (i.e., its benefits), and subtracted from those the government's forecast expenditure (i.e., its costs), in order to determine its Net Present Value (A\$).

# 1.2 The 'Value' model / framework

The key premise of our multi-hazard framework is that the value of assets declines in the presence of pests/diseases, rather than the damage done to assets increasing in their presence. By calculating the relative, rather than absolute, damages associated with each new hazard this subtle distinction ensures that the damages don't exceed the value of the assets. It also simplifies the valuation by allowing hazards with similar absolute damages to be grouped, because their relative impact is zero.

To implement this framework, we:

- estimate the annual flow of benefits arising from each asset;
- distribute the benefit flow across a spatial grid based on each pixel's attributes;
- simulate the arrival of hazards across the grid using a Poisson process;
- disperse them using a combination of leading-edge diffusion and jump dispersal;
- calculate the decline in the value of each asset, given the hazards present in each pixel;
- repeat the process for 50 years, 50,000 times; and
- calculate the average (mean or median) damages.

A model that implements this framework has an enormous number of potential applications; however, it is not currently clear what the full suite of potential applications are, nor the relative levels of demand for them. Further, the model is currently configured as a research tool rather than as user-friendly software, limiting options for its deployment.

# 1.3 Aims and organisation of this report

This report summarises the findings of the Centre of Excellence for Biosecurity Risk Analysis (CEBRA) project 20100401 – User consultation to guide uptake of, and improvements to, the spatio-temporal asset damage model developed during CEBRA Project 170713 ('the Value model'). The purpose of this report is to summarise which stakeholders were consulted, their feedback on the existing CEBRA Value model output, their 'user stories' (where they see potential for using this model in their work) and a description of any extra features required to fulfil these user stories along with an assessment of the data inputs, hardware requirements and software development workload needed for their implementation. A description of the model improvement work completed during the project is also included along with a list of model dependencies (both software and hardware).

Further information about the model can be found in Dodd et al. (2020) and Stoeckl et al. (2020).

# 2 Methods

Several rounds of engagement were undertaken. The initial rounds of engagement were focussed on gathering general feedback supporting the identification of use cases and potential 'quick win' model updates whilst the subsequent rounds were focussed on refining and determining the relative priority of the more substantive proposed improvements. These workshops were augmented with CEBRA's own observations and those of previous reviews when determining priority improvements.

# 2.1 Stakeholder workshops

#### **Initial Meetings**

Engagement with stakeholders commenced with a 1hr meeting with representative(s) of each of the relevant DAWE divisions nominated as having a broad understanding of the division's remit. These meetings began with a short presentation outlining the model framework and the plan for engaging with divisions. Possible use cases were briefly discussed with a view to determining the appropriate people to invite to a workshop and the required background material to be prepared.

#### **Divisional Workshops**

Five 2.5-hour workshops were then held (one per division) following a standard format where the framework was explained to participants, with the opportunity to ask questions, before they were asked to identify: what they thought had been done well; what they would have done differently; and what uses the department might consider for the model. These were each discussed before participants were asked to vote (privately) for up to three priority weaknesses and use cases.

Following the workshops, the project team collated the results into a single set of priorities.

#### Follow-up Meetings

A small number of follow-up meetings with interested stakeholders were held to further clarify the potential use cases, where they weren't already well understood by the project team. These didn't alter the priority rankings identified during the original workshops but rather assisted the team to identify any potential limitations preventing the use of the model framework in that context.

In total, 24 hours of engagement was undertaken by the project team across 15 separate meetings. These meetings have included 42 key divisional representatives from each of the seven divisions (or offices) within the Biosecurity and Compliance Group, the Portfolio Strategy Division and ABARES.

# 2.2 Out-of-session feedback

#### Known limitations / issues

In addition to the potential improvements identified by the departmental participants, the project team nominated several potential improvements that had been flagged in the original report.

#### **CEBRA SAC Reviews**

Lastly, any points of potential weakness raised during the CEBRA Science Advisory Committee (SAC) review of the Key Result Summary (Dodd *et al.*, 2020) were added to the list.

The overall priority of the proposed improvements was determined by identifying the overall impact of the improvement on the priority use-cases relative to the effort required to complete them.

# 3 Results

Our stakeholder engagement identified some 25 (from a total of 50) unique points of positive feedback, 25 (of 45) unique points of potential improvement and 18 (of 36) unique possible use cases. These use cases could be further distilled into six generic 'user stories'. Of the 25 points of potential improvement, ten were suitable for delivery as 'quick-win' model updates. The project sponsor endorsed a plan to deliver seven quick wins over twelve weeks as per the scope.

The specific feedback provided by participants is included, it its unedited form, in Appendix 6.3.

#### 3.1 What was done well

#### Conceptualisation

(11 comments) In the first instance, participants described the project as a careful attempt to tackle a fundamental question. Participants commented that the task had been approached in both a logical and methodical manner and that the theoretical conceptualisation of the framework was sound. In this regard, it was agreed that the macro-scale nature of the framework matched the problem and that the geospatial dimension increased its potential usefulness. Several participants also saw the framework as an opportunity to strengthen links across the department.

#### **Asset Focus**

(5 comments) Participants commented that the focus on assets was sensible, given the multi-hazard focus; in particular, that their classes are consistent with the Total Economic Value (TEV) approach. The effort to avoid double counting and limit damages to asset values was also seen as a strength.

#### **Exemplar Pests**

(3 comments) Participants viewed the use of functional groups as a positive contribution, in part, because some saw it as an opportunity to think more generally about pest/disease impacts.

#### Systems Approach

(6 comments) Participants commented that the systems approach was a potentially useful way to move away from hazard-based assessments that focus on specific pests, commodities or activities. Similarly, the explicit acknowledgement that hazards are not independent was considered by some participants to be a positive step. Participants across several divisions noted that the framework helps to inform our understanding of the data requirements for monitoring performance.

# 3.2 What could have been done differently

#### **Additions**

(5 comments) The addition of impacts on human health and those caused by aquatic organisms (both marine and freshwater) was raised by participants as a potential improvement. Similarly, the addition of post-border control by the jurisdictions was identified as a priority in two workshops.

#### **Alterations**

(8 comments) Several participants made suggestions regarding the RRRA functional groups. These comments centred around the representativeness of the groups and their chosen exemplars. The omission of control costs from the framework was also flagged as a potential area for improvement.

#### Validation

(3 comments) The need for validation of the model's various inputs and outputs was raised as a priority in several of the workshops, both in terms of the functional groups (as discussed above), and the biological (arrival and spread) and economic (impact) components of the model.

#### **Outputs**

(6 comments) The most common suggestion for improvement, across workshops, was for a suite of additional statistics and associated [simple] graphics to be produced. These included estimates of damages broken down by region and/or sector, and the characterisation of co-benefits (spillovers).

#### Out-of-scope

(3 comments) Participants across several divisions suggested that they would have liked to have seen an attempt to separate apart some of the system's controls so that their benefits could be compared. However, this was explicitly out of scope.

# 3.3 Proposed use-cases / user-stories

#### Enhanced collaboration through a shared understanding of risk (US1)

One of the strong themes that came through the engagement was the need to better demonstrate the importance of biosecurity. Although the wording varied across workshops, in each case, the desire was to improve collaboration through a shared understanding of risk. Thus, perhaps the simplest use for the model is as an input to communications and engagement material.

Relevant divisions: All

#### Statutory environmental assessments (e.g., bioregional assessments) (US2)

The potential to use the asset layers within statutory environmental assessments (e.g., Bioregional Assessments) was raised in the Portfolio Strategy workshop, though, this use case is not supported by the project team. This is because the asset layers are built from the top down (using whole of NRM values to infer pixel values), rather than the bottom up (estimating pixel values then summing), meaning that the value of pixels within a region are all equal making them unsuitable for this task.

Relevant divisions: Portfolio Strategy

#### Pest risk [consequence] analysis (e.g., national significance assessments) (US3)

The potential for the model to be used for various types of consequence analysis (e.g., National Significance Assessment, as an input to CBIS, etc.) was raised in several workshops, particularly in the context of improving the transparency and repeatability of the estimation of environmental impacts. However, the project team views this as a longer-term goal, because one of the trade-offs associated with a multi-hazard framework is a reduction in accuracy at the individual hazard level.

Relevant divisions: Biosecurity Plant, Biosecurity Animal, OCEBO, OCPPO, OCVO.

#### **Design** of multi-hazard biosecurity risk controls (US4)

The potential for the model to significantly simplify the process of designing multi-hazard controls (e.g., arbovirus surveillance, ISPM 15, etc.) by making it far easier to estimate their benefits was a known use case prior to the workshops. However, the use of the model for this purpose was consistently prioritised below system optimisation and performance evaluation (discussed next). *Relevant divisions:* All

#### System **optimisation** (i.e., prioritisation and/or resourcing of controls) (US5)

The most commonly proposed use case, identified as a priority in each of the workshops, was to assist with the prioritisation of resources across risk controls. Related to this were numerous suggestions that the model could be used to improve understanding of the value of, and interaction between, the system's parts. This use case is being pursued through CEBRA Project 21D.

Relevant divisions: Biosecurity Strategy and Reform, Compliance, and Biosecurity Operations

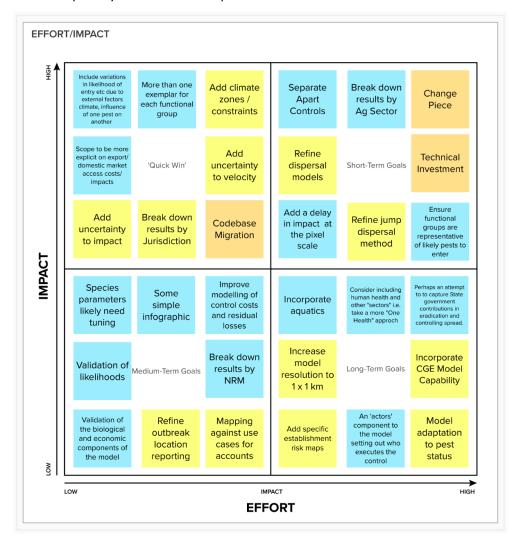
#### Ex-post evaluation of system level performance (US6)

System-level performance evaluation (i.e., the estimation of cumulative effects) was also identified as a priority in each group. Use in this context spanned informing the collection of performance metrics through to the use of performance evaluation to demonstrate the benefits of biosecurity.

Relevant divisions: Biosecurity Strategy and Reform

#### 3.4 Priority improvements

By linking the proposed improvements to the respective use cases, the project team was able to assess the relative priority of each of the improvements. These are discussed in the next section.



# 4 Discussion

## 4.1 Implementation

Quick wins (<2 weeks' work)

#### 1. Add the ability to break down results by jurisdiction - COMPLETED

**Description:** In its original form, the model simply reported an estimate of aggregate damages at the national scale. The purpose of this improvement is to allow for the final damage estimate to be broken down by jurisdiction to improve our understanding of where the benefits are received.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: None

**Software change:** The original code grouped pixel level damages by time and asset. Implementing this change required the NRM region to be retained in the damage object and added to the 'group by' function. Later functions (e.g., plots) that use the same object also required modification.

**Data:** None – NRM codes were already present in the dataset

Hardware change: Minor (+ storage impact) | Effort required: 2 weeks

#### 2. Complete the identification of hardware requirements - COMPLETED

**Description:** Deploying the model effectively within the department (or elsewhere) requires an understanding of the computing resources required to run the model in a feasible timeframe (i.e., less than a week) so that they can be funded and obtained.

**Contributes to user stories:** 3, 4, 5, 6 **Depends on improvements:** None

**Software change:** The project team tested several different deployment types and configurations; including desktop machines, local servers and cloud servers (AWS) as well as different storage configurations (local, network). Software dependencies were also identified during this process.

Data: None

Hardware change: None (see Appendices) | Effort required: 2 weeks

#### 3. Add the ability for the likelihood of entry/establishment to change over time - COMPLETED

**Description:** The original implementation assumed that the likelihood of establishment for each of the functional groups remained constant over time. This is unlikely to be true. Thus, it would be desirable if the model could accept a set of arrival rates, per hazard, rather than a fixed value.

**Software change:** The original code accepted a wide format [40,2] table with a row per hazard. The input was modified to a long format [80,1] table that accepts either a single value, or multiples in columns named by year. These are interpolated, with the model using the *n*th value.

Data: Estimates of future establishment rates (at one or more points in time)

#### 4. Add the ability for multiple exemplar hazards per functional group - COMPLETED

**Description:** The current implementations of both RRRA and the value model assume that a single 'example' pest can be used to represent the damages of each group of hazards. This change would allow for several different example hazards to characterise a group, improving accuracy.

**Contributes to user stories:** 4, 5, 6 **Depends on improvements:** None

**Software change:** Implementing this change required the functional group to be reconceived as a grouping variable and a new species (hazard) variable added for the model to loop over (rather than looping over groups). The damage function was also re-factored to first aggregate by group.

**Data:** None - though, any new exemplars will need parametrisation prior to implementation.

Hardware change: Minor (+ storage impact) Effort required: 2 weeks

#### 5. Add the ability to constrain an exemplar hazard to an extent - COMPLETED

**Description:** The current implementation allows for the exemplar pest to spread throughout the group's entire host range. This change would allow for an exemplar (where there are several) to be constrained to a subset of all host (e.g., tropical horticulture), improving pest-level accuracy.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: 4

**Software change:** Implementing this change required a new input directory to be created where the user can add the output of a Species Distribution Model (SDM) or a binary raster for each exemplar hazard. This is then used to mask/subset the list of host cells for a hazard.

**Data:** None – though, for an exemplar to be constrained to a particular set of cells, the corresponding binary raster (or SDM) must be supplied.

Hardware change: Minor (+ storage impact) | Effort required: 2 weeks

#### 6. Add the ability for price changes to occur due to market access changes - COMPLETED

**Description:** The original implementation of the model was largely (though, not exclusively) focussed on yield losses. This change would allow for price changes to also occur in areas where the hazard is present (though, not in adjacent regions – with the exception of FMD).

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: None

**Software change:** Implementing this change required a new price change input to be created. This is passed to the damage function that has been modified to allow price, yield or both impacts depending on the arguments provided.

Data: None – ABARES already has estimates of the price change for each functional group

#### 7. Prepare the codebase for migration - COMPLETED

**Description:** The model currently only exists as an internal code repository. Therefore, deployment elsewhere requires the consolidation of the code into a stable 'master' branch that is sufficiently commented / documented that it may be used by others outside the research team.

Contributes to user stories: 1, 2, 3, 4, 5, 6 Depends on improvements: None

**Software change:** The project team completed a full end-to-end audit of the codebase ensuring that the code is both functioning correctly and is appropriately commented / documented before merging the above changes into the master and running 50k simulations as a final check.

Data: None

Hardware change: None Effort required: 2 weeks

#### 8. Add the ability for the dispersal distance to vary stochastically

**Description:** The model currently disperses hazards across space at the rate required to achieve the mean spread rates elicited by ABARES. This change would allow for this rate to vary within the range of elicited values (e.g., min, mean, max), across (rather than within) simulations.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: None

**Software change:** Implementation of this change will likely require the range to be included as a new input variable that can be passed to the neighbours function when calculating which cells to spread to. The neighbours list could then be filtered based on a random sample from the range.

Data: None – ABARES already has estimates of the range for each functional group

Hardware change: None Effort required: 2-4 weeks

#### 9. Add the ability for the yield loss to vary stochastically

**Description:** The model currently damages assets at the mean rates elicited/sourced by ABARES. This change would allow for this rate to vary within the range of elicited values (e.g., min, mean, max), potentially both within and across simulations depending on the performance impact.

**Software change:** Implementation of this change will likely require the range to be included as a new input variable that can be passed to the damage function when calculating the pixel scale impacts. Damages could then be assigned based on a random sample from the range.

Data: None – ABARES already has estimates of the range for each functional group

#### 10. Add the ability for a delay in the accrual of damages

**Description:** The model currently assumes that damages are incurred as soon as the hazard arrives in a pixel. However, for some hazards and/or assets this will overestimate the true damages which may not reach the maximum for some years. This change implements that delay.

Contributes to user stories: 3, 4, 5, 6 Depends on improvements: 9

**Software change:** Implementation of this change has the potential to be more complicated now that the yield losses are stochastic. It may be possible to use a lag (linear or logistic) function to estimate the yield impacts, rather than a left join, though, this will significantly impact speed.

**Data:** Estimates of the time to maximum per area impact (dependent on resolution).

Hardware change: None Effort required: 2 weeks

#### Short-term goals (<1 month OR high priority)

#### 11. Add the ability to compare two (or more) controls and vary their effectiveness - 21D

**Description:** The current implementation of the modelling framework assumes that the user has two system states that they wish to compare – on/off – effectively a single control. This change would allow an array of inputs representing multiple controls, allowing their comparison.

**Contributes to user stories:** 4, 5, 6 **Depends on improvements:** None

**Software change:** Implementation of this change will likely involve a re-factoring of the looping over system states (and the processing of results) so that it can accept an array of input settings. This change is currently a deliverable of CEBRA project 21D.

Data: None

**Hardware change:** Moderate (x2-4 storage) **Effort required:** 4-8 weeks

#### 12. Add the ability to break down results by agriculture sector / industry

**Description:** The current implementation of the model reports aggregate damages to agriculture. This change would allow those results to be broken down to high-level sectors, (e.g., livestock, broadacre, horticulture, forestry, etc.), possibly by region or jurisdiction.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: 1, 16

**Software change:** Implementation of this change will likely involve retaining the land use data in the damage object similar to improvement 1, though, it probably makes more sense to pursue this after improvement 16 and use the occupancy method as it will be far more efficient.

Data: None

#### 13. Add the ability to model disease transmission via a [gravity] network

**Description:** The current implementation of the model is grid based, which more closely matches the methods used in plant health and invasive species contexts. This change would implement a network model, which is more common in animal health, for those functional groups.

**Contributes to user stories:** 3, 4, 5, 6 **Depends on improvements:** None

**Software change:** Implementation of this change will likely involve two changes. The first will be to re-factor the code to model iterations within hazards, rather than hazards within iterations. The second will be to develop a new dispersal function that uses network-based methods.

Data: Abstracted NLIS network dataset

Hardware change: None Effort required: 4-8 weeks

#### 14. Add the ability for jump dispersal to occur based on pixel attributes - MDAP

**Description:** The current implementation of the model assumes that jumps from a pixel occur at a fixed rate (per hazard) independent of the attributes of the pixel. This change would allow for the number of jumps from a pixel to vary dependent on a weight determined from its population, etc.

**Contributes to user stories:** 3, 4, 5, 6 **Depends on improvements:** None

**Software change:** Implementation of this change will require the creation of weights for each of the hazards (using some combination of the human population, livestock density etc) which can then be passed to the jumps function and used to scale the number of jumps.

Data: None – though, there is a link with 13 above and the NLIS abstraction could add value here.

Hardware change: None Effort required: 4 weeks

#### 15. Improve spatial representation of intensive industries

**Description:** The current implementation of the model uses two-digit land use codes to define the host layer. This means that some of the intensive animal industries (e.g., piggeries and feedlots), which share a two-digit code (52), are lumped together when the land use of the pixel is assigned (which would cause issues if modelling ASF, for example). This change will correct that.

**Software change:** Implementing this change will most likely require the creation of custom tertiary land uses (7XX) and a function to assign those to the problematic land uses so that they are retained when converted to two-digit codes. The relevant host lists will also require updating.

Data: None

#### Medium-term goals (1-3 months OR medium priority)

#### 16. Add the ability to break down results by region (e.g., SA4 or NRM) - MDAP

**Description:** Improvement 1 added the ability to break results down by jurisdiction, however, it was not possible to report the full distribution of possible damages at the SA4 or NRM level as the objects are simply too large ( $50,000 \text{ sims } \times 56 \text{ NRMs } \times 50 \text{ years } \times 16 \text{ assets} = 2.2 \text{ billion rows}$ ).

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: None

**Software change:** Through our collaboration with MDAP we have identified that it is possible to calculate the mean impact (down to the pixel scale) using the hazard's respective probabilities of occurrence, which in turn can be derived from arrival and spread rates. Though, this approach would need to be coded and a new damage function written.

Data: None

Hardware change: None Effort required: 2 weeks

#### 17. Add the ability to model specific control costs

**Description:** The original implementation of the model was largely (though, not exclusively) focussed on yield losses. This change would allow for control costs to also occur in areas where the pest/disease is present (separately from costs associated with market access requirements).

**Software change:** Implementing this change will likely require a new control cost input to be created. Consideration will also need to be given to the relationship between yield loss and control costs to avoid double counting. Both inputs will be passed to a revised damage function.

Data: None – ABARES already has estimates of the control costs for each functional group

Hardware change: None Effort required: 2 weeks

#### 18. Fix the issue where 'lightning strikes twice' in the same cell but is only recorded once

**Description:** To ensure the model is functioning correctly, we analyse (retrospectively) when and where new outbreaks occur across the landscape. Currently, if a second outbreak arises in the same pixel then it isn't counted in the total. This change would correct that.

**Contributes to user stories:** 4, 5, 6 **Depends on improvements:** None

**Software change:** This behaviour has no effect on the final damage estimate; it's simply a check. Implementing this change will most likely involve adding a counter that saves outbreak locations separately rather than approximating the answer from existing model outputs, as we do now.

Data: None

#### 19. Add the ability to generate some simple infographics for use with industry stakeholders

**Description:** The model currently produces high level summary statistics and diagnostic plots. The majority of these are not intended for a general audience and this limits the usefulness of the model. This change would be to investigate some simple graphics that better convey key results.

Contributes to user stories: 1, 3, 6 Depends on improvements: 12, 16

**Software change:** Implementing this change will require stakeholder consultation in addition to the subsequent codebase changes. Specific requirements will depend on the exact request, though, it should be noted that graphics can take considerable time to develop and finesse.

Data: None

Hardware change: None Effort required: 4 weeks (per infographic)

#### Long-term goals (>3 months OR low priority)

#### 20. Add the ability to model zoonotic organism dispersal, values and impacts

**Description:** The modelling of impacts on human health was treated as out of scope for the value project to help ensure that the project remained tractable. This change would extend the modelling to include transmission of zoonotic disease to humans and an estimation of impacts.

**Software change:** Implementing this change will require, at a minimum, an estimate of the attackrate for each zoonosis, the associated morbidity and mortality effects and an estimate of the value of human health. Secondary transmission could also be modelled, as a next step.

Data: As above

Hardware change: None Effort required: 1-2 years

#### 21. Add the ability to model aquatic species dispersal, values and impacts

**Description:** The modelling of impacts on aquatic ecosystems was treated as out of scope for the value project to help ensure that the project remained tractable. This change would extend the modelling to include aquatic species (both marine and freshwater) and an estimation of impacts.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: 13

**Software change:** Implementation of this change will require estimates of dispersal rates to be gathered, and a corridor/linear dispersal method developed (following improvement 13). Estimates of the value of assets will also need to be sourced.

Data: As above, plus a waterways layer, a digital elevation model, and an ocean current diagram

#### 22. Add the ability to model post-border interventions / controls

**Description:** The current implementation of the model assumes that hazards spread freely once established; that is, there are no post-border controls. This change would add the ability to include control measures that remove populations, slow spread and/or reduce per-area effects.

Contributes to user stories: 4, 5, 6 Depends on improvements: None

**Software change:** Implementing this change will require the addition of a fourth 'control' step to the core arrival, spread, impact sequence. Controls will likely be coded as generic functions that can be deployed based on context specific rules (e.g., x control removes y% of populations). Though, other controls will also need to be applied within the arrival, spread and impact steps.

**Data:** Estimates of control efficacy, rules about how the controls are applied.

Hardware change: None Effort required: 6-12 months

#### 23. Add, or enable a link to, Computable General Equilibrium (CGE) model functionality

**Description:** The current implementation of the model includes only direct 'first round' impacts on assets. This change would add the ability to consider the indirect 'second round' impacts on other sectors that would arise from a shock to the agriculture sector via a CGE model.

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: 12

**Software change:** Implementation of this change will first require the completion of improvement 12 to determine the size of the productivity 'shock' for each sector. That output will likely then be passed to the CEBRA sub-national CGE model (coded in C++) and solved recursively.

Data: None

Hardware change: None Effort required: 3 months

#### 24. Increase the scale of the modelling grid to 1x1km (from 2.5 x 2.5km) - MDAP

**Description:** The current implementation of the model uses a 2500m pixel resolution. This means that intensive industries, which have a small geographic footprint, sometimes drop out of the landscape when the land use of the pixel is determined. This change will correct that.

**Software change:** Implementation of this change is currently being pursued via several different strategies as part of our MDAP collaboration. Primarily, we're looking at mathematical methods used to solve fluid dynamics and particle physics problems in conjunction with GPU hardware.

Data: None

Hardware change: Moderate (+GPU) Effort required: 6 months

#### 25. Add the ability to assign specific establishment risk maps for a hazard

**Description:** The current implementation of the model assumes that the risk of a hazard arriving at a location is the same for each hazard and is constrained only by host availability. This change would allow the user to input a specific risk map for each hazard, similar to improvement 5.

**Contributes to user stories:** 1, 3, 4, 5, 6 **Depends on improvements:** None

**Software change:** Improvement 5 (completed during this project) has partly implemented this change as it allows for arrival to be weighted by both climate match and population density. Thus, the change here would be to add an additional risk map input that could further augment that.

**Data:** None – the required data is already held by CEBRA, ABARES and the RRRA team (see CEBRA 170607), though, the various datasets would need to be analysed to produce the risk map inputs.

Hardware change: None Effort required: 1 week

#### 26. Add the ability to assign an 'actors' tag that allows tracking of 'who' executes controls

**Description:** The current implementation of the model effectively treats the entire system as a single intervention. This change, which is dependent on these controls being disaggregated, would add a tag to each of the controls to allow their individual performance to be measured.

Contributes to user stories: 4, 5, 6 Depends on improvements: 11, 22

**Software change:** It is currently difficult to know how this change will likely be implemented as the model currently utilises the RRRA model for its control typology and will continue to do so until after CEBRA Project 21D is complete. Though, it's unlikely to be difficult.

Data: None

Hardware change: None Effort required: TBC

#### 27. Add the ability for changes in land-use, climate, host-presence, etc. to occur over time

**Description:** The current implementation of the model assumes that the landscape is static. This change would allow for land uses and/or climate suitability (i.e., host presence) to change over time – most likely in response to pest/disease status (e.g., transitioning to an alternate crop).

Contributes to user stories: 1, 3, 4, 5, 6 Depends on improvements: None

**Software change:** Implementing this change could be quite difficult, possibly intractable, given that much of the current implementation is predicated on the attributes of the grid remaining static. Though, it may be possible to implement in one of the alternate approaches currently being explored through the MDAP collaboration – if the triggers for transition can be sourced.

**Data:** Estimates of land use transition rates (and their triggers), SDMs for different scenarios.

Hardware change: Moderate (+GPU) Effort required: 1-2 years (pending MDAP)

#### 4.2 Non-model improvements

In addition to the potential improvements to the modelling framework and its implementation, participants identified several additional priority activities that they considered essential to the modelling framework being adopted within the department.

#### Validation

Validation was raised as a priority in several of the workshops reflecting the importance of validation as a due diligence exercise in any simulation modelling project. In simple terms, validation is about ensuring that the model makes sensible predictions. This is critically important if a model is to be deployed into practice. Priorities for validation include:

- the functional groups, and their respective exemplars;
- the RRRA likelihood estimates;
- the hazard's [demographic] inputs; and
- the simulation results (using a subset of hazards).

We suggest that about 12 months of effort should be allocated towards such a validation exercise.

#### **Departmental Activities**

Several workshop participants suggested that additional support would be required within the department to facilitate the adoption of modelling and analytic tools, including the value model. These supports included:

- · Technical investment in modelling capacity and capability; and
- A change piece supporting the transition to increased use of modeling and analytics.

Our experience suggests that this would be beneficial.

# 4.3 Current projects

#### CEBRA - MDAP Collaboration

The project team are currently collaborating with colleagues from the University of Melbourne's Data Analytics Platform (MDAP) to test alternate implementations of the model logic with a view to substantially improving its speed. This collaboration will likely deliver improvements 14, 16 and 24.

#### **CEBRA Project 21D**

The project team have also commenced work on CEBRA Project 21D. That project seeks to develop a transparent and repeatable model for comparing the relative costs and benefits of different levels of intervention within and across two pilot pathways which requires (will deliver) improvement 11.

#### 4.4 Conclusions

Our conversations with departmental stakeholders revealed that they saw the value model framework as a logical and methodical approach to tackling a fundamental question in biosecurity. Nevertheless, a wide range of potential opportunities for improvement were identified – ranging from minor modifications, through to significant additional functionality – for implementation prior to the adoption of the model within the department. Several potential use cases exist across the department, the most widely supported being the allocation of resources between competing risk controls. This use case is being pursued by CEBRA project 21D with a proof-of-concept tool due for delivery in 2023.

# 5 References

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# 6 Appendices

The following requirements are based on version 0.2.0 of the value model (i.e., values package). This version can be sourced from commit SHA 407ebfb64d3a07d133e288f951b03521ad5ef360.

# 6.1 Software Requirements

#### Ubuntu

#### Ubuntu 18.04 LTS

GCC compiler

build-essential 12.4ubuntu1 manpages-dev 4.15-1

Matrix operations

libopenblas-dev 0.2.20+ds-4

**Dependencies** 

sqlite3 3.22.0-1ubuntu0.4 libsqlite3-dev 3.22.0-1ubuntu0.4 pkg-config 0.29.1-0ubuntu2

libssl-dev 1.1.1-1ubuntu2.1~18.04.10

libcurl4-openssl-dev 7.58.0-2ubuntu3.14

libxml2-dev 2.9.4+dfsg1-6.1ubuntu1.4 libmagick++-dev 8:6.9.7.4+dfsg-16ubuntu6.11

**Geospatial binaries** 

libgdal-dev3.0.2+dfsg-1~bionic2libproj-dev6.2.1-1~bionic0gdal-bin3.0.2+dfsg-1~bionic2

libudunits2-dev 2.2.26-1

libgeos-dev 3.8.0-1~bionic0

R

r-base 3.6.1-3bionic r-base-dev 3.4.4-1ubuntu1 r-recommended 3.6.1-3bionic r-base-html 3.4.4-1ubuntu1

**Python** 

python3.6 3.6.9-1~18.04ubuntu1.4

#### **Python**

#### **Python 3.6.9**

geopandas 0.5.1-2~bionic0 rasterio 1.1.3-1~bionic0 shapely 1.6.4-5~bionic0 numpy 1:1.13.3-2ubuntu1

# **R** version and packages

# R 3.6.1

ВН	1.69.0-1	isoband	0.2.4	stars	0.4-0
DBI	1.0.0	jpeg	0.1-8.1	stringi	1.4.3
R6	2.4.0	jsonlite	1.6	stringr	1.4.0
RColorBrewer	1.1-2	knitr	1.25	sys	3.3
RCurl	1.98-1.3	labeling	0.3	tibble	2.1.3
Rcpp	1.0.2	later	1.0.0	tidyr	1.0.0
abind	1.4-5	latticeExtra	0.6-28	tidyselect	0.2.5
animation	2.6	lazyeval	0.2.2	tinytex	0.16
askpass	1.1	lifecycle	0.1.0	units	0.6-5
assertthat	0.2.1	lwgeom	0.1-7	utf8	1.1.4
backports	1.1.5	magick	2.7.2	vctrs	0.2.0
base64enc	0.1-3	magrittr	1.5	viridisLite	0.3.0
bitops	1.0-6	markdown	1.1	withr	2.1.2
cellranger	1.1.0	mime	0.7	xfun	0.10
classInt	0.4-2	munsell	0.5.0	xml2	1.2.2
cli	1.1.0	openssl	1.4.1	xtable	1.8-4
clipr	0.7.0	packrat	0.6.0	yaml	2.2.0
colorspace	1.4-1	pillar	1.4.2	zeallot	0.1.0
crayon	1.3.4	pkgconfig	2.0.3	Z00	1.8-6
crosstalk	1.0.0	plogr	0.2.0		
curl	4.2	plotly	4.9.3		
data.table	1.12.4	png	0.1-7		
digest	0.6.21	prettyunits	1.0.2		
dplyr	0.8.3	progress	1.2.2		
e1071	1.7-2	promises	1.1.0		
ellipsis	0.3.0	purrr	0.3.3		
evaluate	0.14	raster	3.0-12		
fansi	0.4.0	rasterVis	0.46		
fastmap	1.0.1	readr	1.3.1		
flock	0.7	readxl	1.3.1		
fst	0.9.0	rematch	1.0.1		
gdalUtilities	1.0.0	remotes	2.3.0		
ggplot2	3.3.3	reticulate	1.13		
ggtext	0.1.1	rgdal	1.4-8		
glue	1.3.1	rgeos	0.5-2		
gridtext	0.1.4	rlang	0.4.2		
gtable	0.3.0	rmarkdown	1.16		
hexbin	1.28.0	rnaturalearth	0.1.0		
highr	0.8	scales	1.0.0		
hms	0.5.1	sessioninfo	1.1.1		
htmltools	0.4.0	sf	0.8-1		
htmlwidgets	1.5.3	shiny	1.4.0		
httpuv	1.5.2	sourcetools	0.1.7		
httr	1.4.1	sp	1.3-2		

# 6.2 Hardware Requirements

The model itself has no specific hardware requirements (i.e., it will run on a standard PC), though, the time required to complete a meaningful number of simulations will be impractically long.

Performance benchmarking done during the quick-wins phase of the project indicates a current speed of approximately 14 simulation pairs (ON/OFF) / core / hour (simulations only) for 40 hazards at 2500m resolution over 50 years with convergence statistics indicating that 25,000 simulations are required for a precision (standard error of the mean) of 0.5 billion. If we are to assume that a week is an acceptable time frame to generate a result, then the following requirements exist:

Compute: 24 CPU

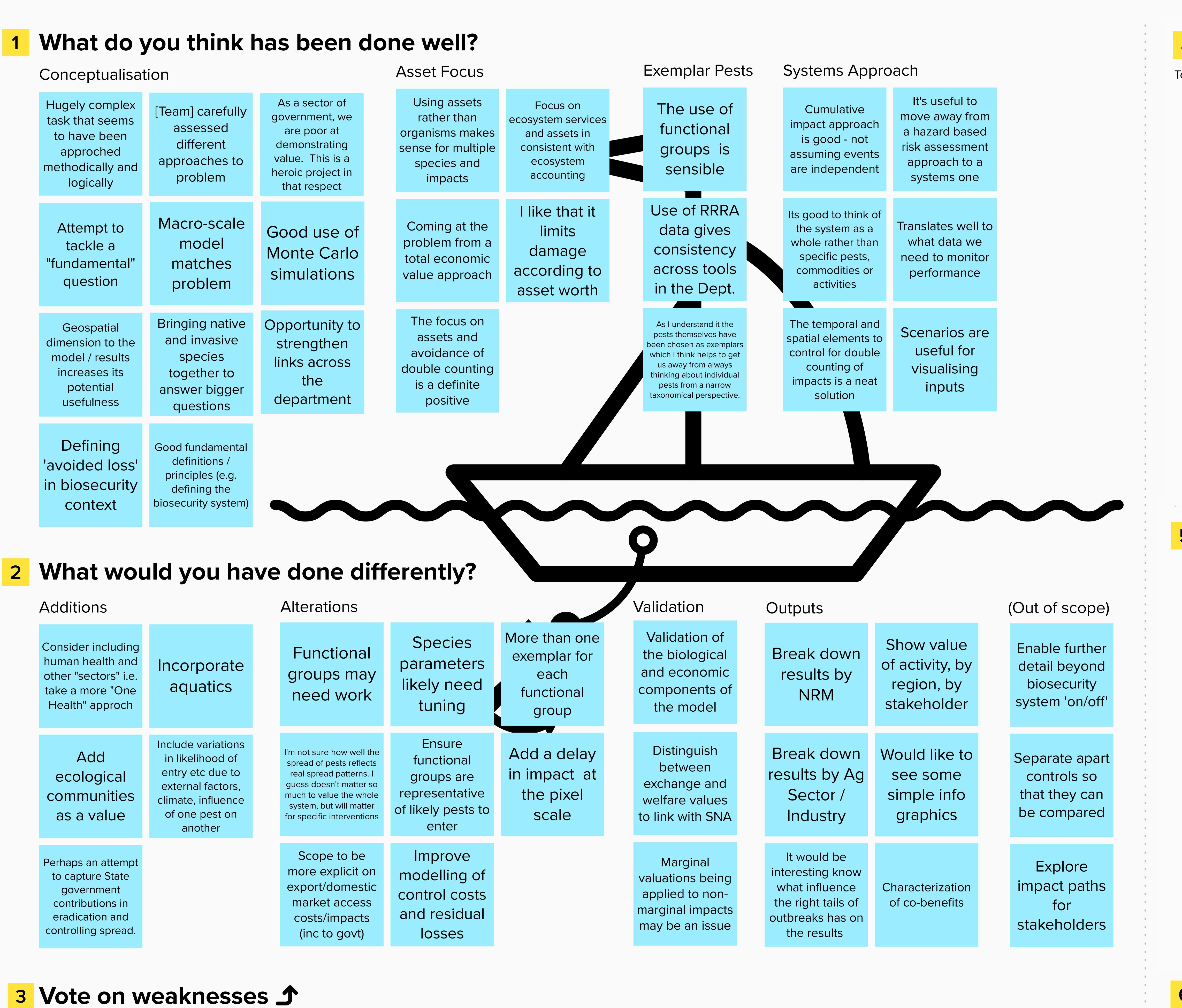
Memory: 192 GB (8GB RAM / core)

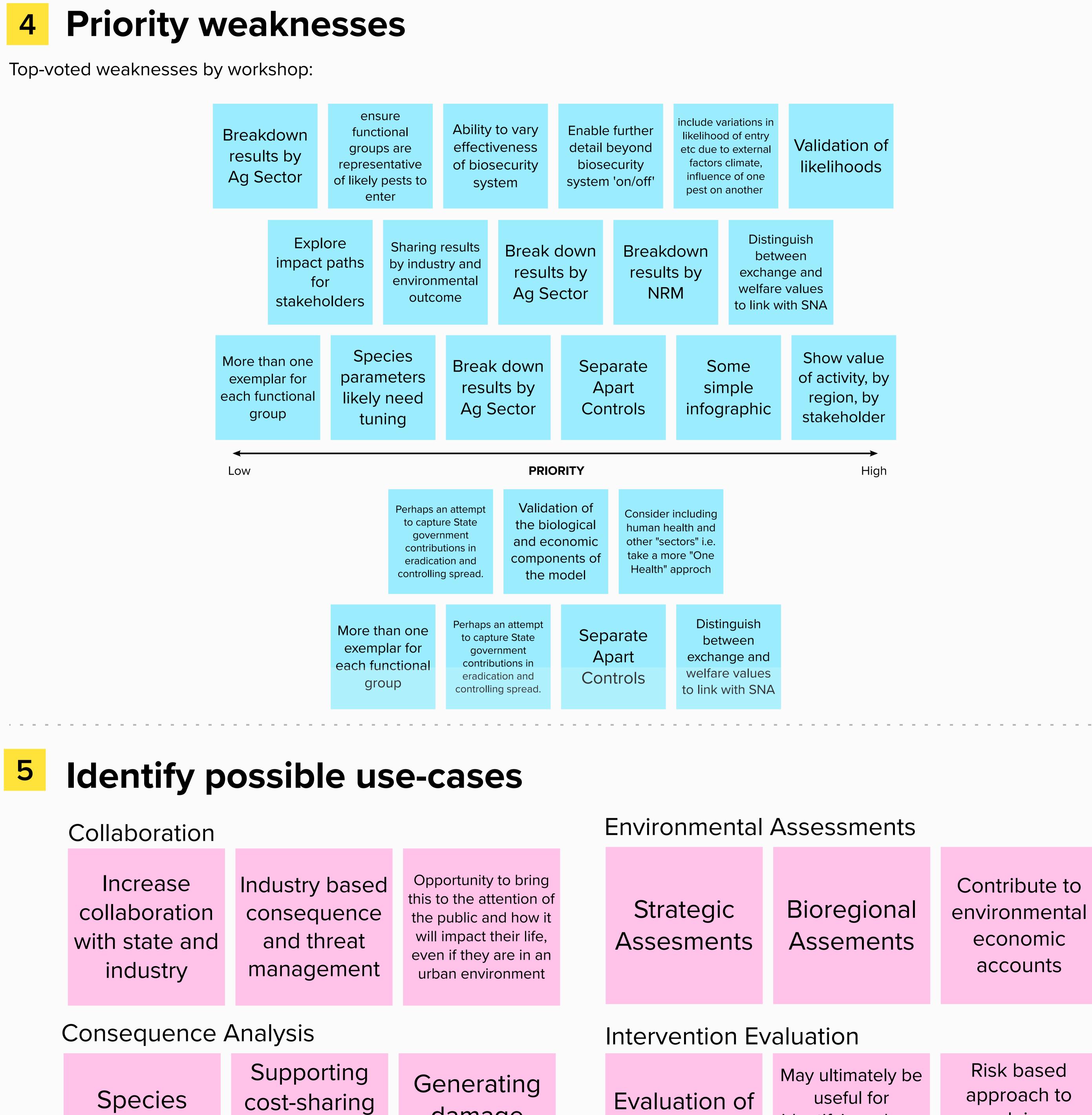
Storage: 500GB SSD (100GB Inputs, 400GB Results)

NB: This assumes an operating system capable of exploiting the hardware (i.e., Ubuntu or MacOS).

Work is currently underway to re-factor the implementation of the model logic (which was originally designed with a focus on flexibility rather than speed) using different analytical and computational techniques and this will likely reduce these requirements in the medium term. The only potential increase may involve the use of a GPU based implementation, though, this is yet to be confirmed.

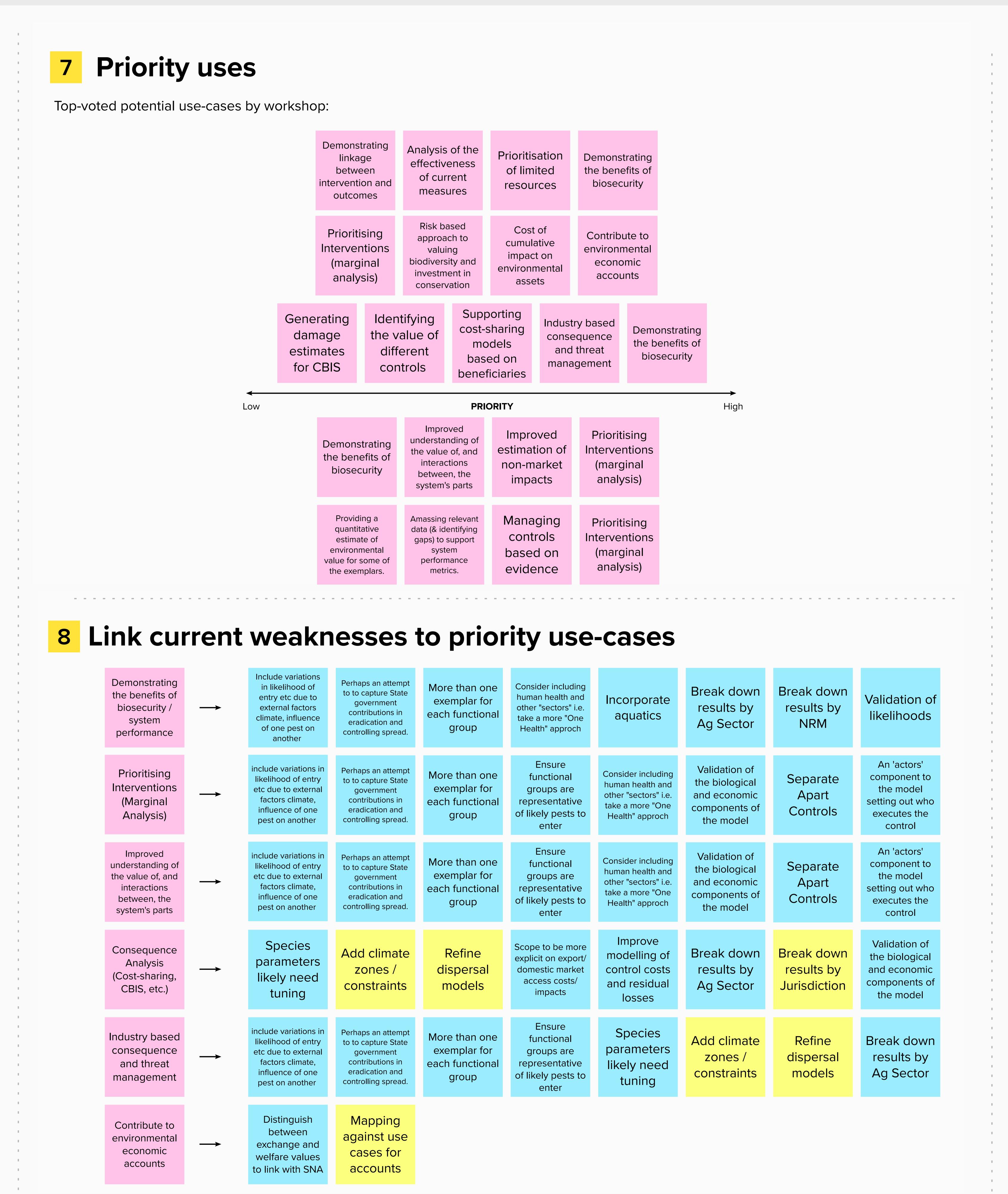
# CEBRA Value Model Engagement

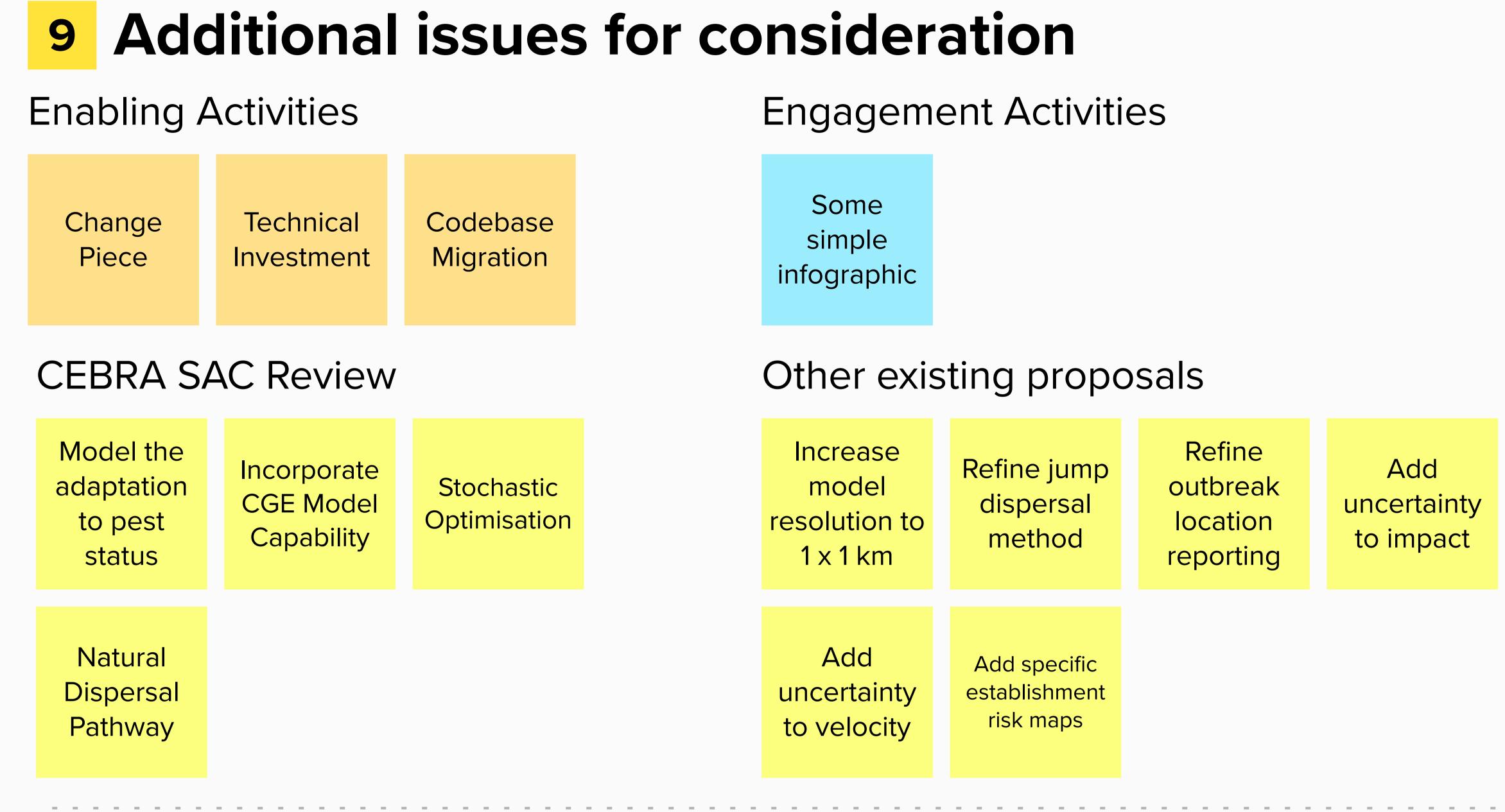




System Optimisation

Vote on uses 1





# Decide what to execute on

