H2020-SFS-2018-2020

DECIDE

Data-driven control and prioritisation of non-EU-regulated contagious animal diseases

Deliverable 3.2

Prototype of decision support tools

WP3 – Integration of data tools in disease control programs

Authors Jenny Frössling, Gema Vidal, Wiktor Gustafsson (SVA), Luis Pedro Carmo, Victor Henrique Silva de Oliveira (NVI), David Graham (AHI), Suhaib Ahmed (SRUC), Stan Jourquin (UGent), Yara Slegers (UU), Camille Delavenne (AUSVET), Lucía Dieste Pérez, Anouk Veldhuis (GD), Sébastien Picault (INRAE), Carla Gomes (AHI), Maria Costa (SRUC), Beatriz García Morante (IRTA), Carolina Mendes Galante Merca, Leonardo Víctor de Knegt (UCPH)

Lead participant SVA

Delivery date 23 December 2024

Dissemination level Public

Type Report

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000494.

Revision History

Author Name (Partner short name)	Description	Date
Jenny Frössling, Gema Vidal (SVA), Luis Pedro Carmo (NVI)	Draft deliverable version 0.0	03.10.2024
Jenny Frössling, Gema Vidal, Wiktor Gustafsson (SVA), Luis Pedro Carmo, Victor Henrique Silva de Oliveira (NVI), Stan Jourquin (UGent), Yara Slegers (UU), Camille Delavenne (AUSVET), Lucía Dieste Pérez, Anouk Veldhuis (GD), Sébastien Picault (INRAE), Carla Gomes (AHI), Annette Boerlage, Maria Costa (SRUC), Beatriz García Morante (IRTA), Carolina Mendes Galante Merca, Leonardo Víctor de Knegt (UCPH)	Draft deliverable version 0.1	15.11.2024
Jenny Frössling, Gema Vidal, Wiktor Gustafsson (SVA), Luis Pedro Carmo, Victor Henrique Silva de Oliveira (NVI), Stan Jourquin (UGent), Yara Slegers (UU), Camille Delavenne (AUSVET), Lucía Dieste Pérez, Anouk Veldhuis (GD), Sébastien Picault (INRAE), Carla Gomes (AHI), Annette Boerlage, Maria Costa (SRUC), Beatriz García Morante (IRTA), Carolina Mendes Galante Merca, Leonardo Víctor de Knegt (UCPH)	Draft deliverable version 0.2	25.11.2024
Jenny Frössling, Gema Vidal, Wiktor Gustafsson (SVA), Luis Pedro Carmo, Victor Henrique Silva de Oliveira (NVI), Stan Jourquin (UGent), Yara Slegers (UU), Camille Delavenne (AUSVET), Lucía Dieste Pérez, Anouk Veldhuis (GD), Sébastien Picault (INRAE), Carla Gomes (AHI), Annette Boerlage, Maria Costa (SRUC), Beatriz García Morante (IRTA), Carolina Mendes Galante Merca, Leonardo Víctor de Knegt (UCPH)	Draft deliverable version 0.31	06.12.2024
David Graham (AHI)	Revision version 0.32	16.12.2024
Jenny Frössling, Gema Vidal, Luis Pedro Carmo	Final draft deliverable v0.4	20.12.2024
Gerdien van Schaik, Johannes Ripperger	Formal checks	20.12.2024
Jenny Frössling, Gema Vidal, Luis Pedro Carmo	Final version 1.0	23.12.2024

Contents

Abbreviations

Abbreviation	Description
API	Application programming interface — a software intermediary that allows two applications to talk to each other.
AWS	Amazon Web Services
BRD	Bovine respiratory disease
EU	European Union
H2020	Horizon 2020
HI	Hemagglutination inhibition
PCR	Polymerase chain reaction
PLF	Precision livestock farming
TRL	Technology readiness level
URL	Uniform Resource Locator – an address on the Web
VDL	Veterinary diagnostic laboratory
WP	Work Package

Partner short names

Short name	Organisation
UU	Universiteit Utrecht
UCPH	Københavns Universitet
UGent	Universiteit Gent
ETHZ	Eidgenössische Technische Hochschule Zürich
UoN	The University of Nottingham
SVA	Statens Veterinärmedicinska Anstalt
INRAE	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environement
NVI	Veterinærinstituttet – Norwegian Veterinary Institute
IRTA	Institut de Recerca i Tecnologia Agroalimentàries
SRUC	Scotland's Rural College
AHI	Animal Health Ireland Initiative
GD	Gezondheidsdienst voor Dieren B.V.
AUSVET	Ausvet Europe
accelCH	accelopment Schweiz AG
HFP	Human Factors Partners

Executive Summary

This deliverable provides an update of the tools under development in the project. We also present how we have classified and grouped the tools into different tracks, to clarify strategies to move forward in development and evaluation. This will be partly informed by the results from a workshop summarized in this report.

Objectives of the Deliverable

With this deliverable, we have made an updated summary and new analysis of the tools under development. The objective is to describe and share the progress we have made in tool development, and to describe opportunities and challenges that tool developers experience. Furthermore, it guides continued development and focuses efforts on evaluation of tool usability and usefulness. This helps tool developers and other WPs to target their work and contribute to WP3.

Activities

Project participants were engaged in various activities that contributed to the outcomes summarized in this deliverable:

1 Monthly meetings between WP3 lead (SVA) and co-lead (NVI) team.
2 Monthly meetings with partners involved in the development of tools.
3 Meetings with smaller groups (i.e., species data groups) for in-depth discussions to better understand each tool being developed.
4 Regular communications with different partners to foster collaboration across species on how to best plan and advance tool development.
5 Meetings with other WPs to coordinate efforts and look for synergies.
6 Organized workshop (June 2024) to provide overview of challenges faced by tool developers at different steps of the development process, and discussion on potential solutions.
7 Guide tool evaluation.

Outcomes

- Description of each tool being developed and overview of their categorization according to their development stage and a set of criteria.
- Brief summary of most relevant challenges for the tool development process identified during the WP3 workshop.
- Identification of areas that need attention in the next step in the work with each group of tools.

Next steps

To establish and to carry out a final evaluation plan for each piloted prototype in order to investigate their usability and usefulness.

Further improvement of tools, such as adding new content, functions and outputs, or adjusting the user interface, based on progress in WP1, WP2, WP4, and WP5.

Ensure that all components of the tool packages (“off-the-shelf tool”) are in place.

Follow-up on the challenges and solutions identified in the WP3 workshop in Nantes, such as gaps in IT infrastructure and security, or sustainability.

1 Analysis and synthesis

1.1 Input sources for assessment of the prototypes of decision support tools

This deliverable is based on several sources and activities. The WP3 leadership engaged with the tool developers to gather information related to the tool descriptions, their categorization and the activities to be conducted in the future.

We have also had monthly meetings with partners involved in the development of tools, and meetings between WP3 lead (SVA) and co-lead (NVI) team, to share experience from both previous and ongoing work on tool development. The expertise of project partners and previous experience has also been discussed and shared through the species data groups.

In June 2024, WP3 organized a workshop to document the challenges faced by the project team during the tool development process. Furthermore, the workshop provided insights into how the tool developers dealt with the different hindrances and potential solutions to overcome them. The workshop design, results and conclusions are included in this deliverable under section 2.

1.2 Overview and assessment of prototypes

In the first and second project periods, almost 20 potential tools were initiated, and in our first WP3 deliverable (D3.1), 16 tools were presented. Since then, development of some tools has been stopped due to limitations in data availability/access or prioritization based on input from stakeholders. We have also merged or added functions from other tools, and in some cases, we have also expanded the development of country-adapted versions of the same tool (the updated list of tools is shown further down in this document, see Table 2). In the last project period, we have had a general focus on identifying potential connections between tools, and between WP3 and other WPs. As part of this deliverable, we have grouped tools based on a set of criteria (Table 1) and set up plans for the continued work.

In the previous deliverable D3.1 and in innovation reports from the project, we have used technology readiness level (TRL) to describe the current and planned status of the tools under development. However, there are other aspects that may be of relevance and that are not captured by the TRL scale. For example, the KTH Innovation Readiness Level[1] includes not just TRL, but also the readiness levels for five additional key dimensions: Customer, Business model and market opportunity, Intellectual property rights, Team, and Funding. For this deliverable, we have broadened the TRL classification and assessment of tools to include more aspects relevant for us. The purpose is to support the planning and prioritisation of our efforts in the remainder of the project. Assessments about the status and plans for the different tool were based on the criteria/questions listed in Table 1 below. Replies to these questions were not treated as definitive criteria but used as a basis for discussion and final conclusions.

[1] https://kthinnovationreadinesslevel.com/

Table 1. Set of criteria used for assessment of progress and classification of tools. In the first column, '*' indicates that the criterion is considered very relevant for a tool to be prioritized for technology demonstration within the project.

	Question/criterion	Relevance
*	Stakeholder involvement, including back and forth discussions	Engagement of stakeholders is key for assuring the usefulness of the tools, their successful implementation and their sustainability in the long run.
*	At least 1 user evaluation of the tool prototype followed by tool development (performed or planned)	Scientific and coordinated evaluation with follow-up development allows for sound conclusions and comparison across tools, the evolution of the tool, and its adaptation to the user needs.
*	Involvement of other WPs	Collaboration between WPs is at the core of the DECIDE plan. Engaging with different WPs might help in the development of a more complete tool.
*	Open code	Open code is of relevance for the generalizability of the tools and part of the project policy.
*	Clear plan for implementation beyond DECIDE:	A sustainability plan is of great importance to increase the chances that the tools live beyond DECIDE. Tool developers and stakeholders should be able to answer questions regarding who will be responsible for tool maintenance, who will host the server where the tool will be located, or development of business plans if needed.
*	Developed within DECIDE	Development of tools within DECIDE is prioritized.
	Implemented in more than one country	When possible, implementation across countries gives further assurances of the generalizability of the tool and its relevance in a European context.
	Implemented in more than one species	As described for the point above, implementation across species proves the value of the tool in various contexts.
*	Has a user interface (dashboard)	The existence of a user interface demonstrates that the tool is developed beyond pure analysis of the data. This is an important step in the co-creation and user evaluation of a tool.
	Provides innovative analysis of animal health data or surveillance data	Innovative approaches are of relevance to distinguish the new tools from others that already provide relevant information to the users.
	Presents output from data analysis / modelling	Inclusion of output from analysis/modelling demonstrates that added value in data is captured and new information is generated.
	Provides recommendations in order to make decisions	The ultimate goal of DECIDE is to support decision making in the context of animal health and welfare.
*	Metadata exists	Generating metadata will help in the use of DECIDE´s tools in the future. Metadata has been identified as a relevant gap when it comes to the use of datasets in animal health.
*	Tool in open repository	Having the tool in an open repository creates better conditions for others to use it and, therefore, for its generalizability and reusability in the future
*	Includes training material	Training material is of relevance for future non-DECIDE developers to reuse our tools.
*	All elements of the tool are collated as a package, container, etc. to facilitate installation	Such a process will facilitate the dissemination and use of the tools.
*	Open repository includes information on how to use the tool, including data sample	As for the point above, this will help in the dissemination and use of tools by other interested parties. Having example data will also help in understanding what is required to make the tool work.
	At least one manuscript submitted to a research journal (eval., modelling)	Scientific manuscripts attest some degree of scientific innovation is integrated into the tool and is also part of tool dissemination.

We have found that the tools that are under development in DECIDE are mainly co-creation tools, data analysis innovation tools, or both. The co-creation tools are tools developed in close collaboration with users/stakeholders. These tools are useful in the dialogue with stakeholders to demonstrate the value of, 1) sharing data and secondary use of existing data, 2) data visualization, and to 3) identify needs and discuss potential use. They are also used to investigate and co-create the user interface and content of tools, and to identify technical requirements, barriers and solutions. Ultimately, they are valuable for the research on tool usability and usefulness.

The data analysis tools have been focused on capturing information about existing data sources through data analysis and modelling. They are used to demonstrate what output and additional value/use can be generated from existing data sources. Some are innovations of new methods in animal health work and surveillance. Even though some are expected to need further development (after the project) to be implemented, these tools will also help meet user needs. The tool algorithms may also be integrated into another tool under development, as an add-on function.

Our original aim has been to develop and make project investigations as complete as possible for 1-2 tools per species. Based on our status assessment, we currently have 4 tools that have reached or will soon meet most of the project criteria and have a high enough readiness level for a technology demonstration track. In addition, we have 10 promising tools that will be used for co-creation and data analysis within and potentially beyond the project.

Table 2. Updated list of tools including overview of results from classification of tools. Animal icons indicate the species for which each tool is implemented. There are four main groups of tools, with some overlap between categories. Row colours (blue, pink, white, and grey) highlight the primary group affiliation of each tool: blue – tools prioritized for technology demonstration; pink - tools for stakeholder co-creation; white - tools for data analysis innovation; grey – tools for which the development was paused.

Tool	Prioritized for technology demonstration	Continued for stakeholder co-creation	Continued for data analysis innovation	Develop-ment paused
Barometer	✓	✓		
BRD tools (Connect'BRD, Eval'BRD)	✓	✓	✓	
Abattoir Inspect	✓	✓	✓	
Laksetap	✓	✓	✓	
Salmon Mortality Monitor		✓	✓	
PigPeaks		✓	✓	
Pig herd health dashboard		✓		
Pig HealthCheck System		✓		
Purchase Assistant		✓		
Broiler Virus Circulation		✓	✓	
Broiler Monitoring Dashboard			✓	
Salmon SyS		✓	✓	
Early Disease Warning Pigs			✓	
Early Warning Calf Mortality			✓	
Purchase Risk Meter				✓
Lely Calf Health Support Tool				✓

1.3 Conclusions and recommendations from the classification of tools

As indicated in Table 2, there are four main groups of tools (Figure 1).

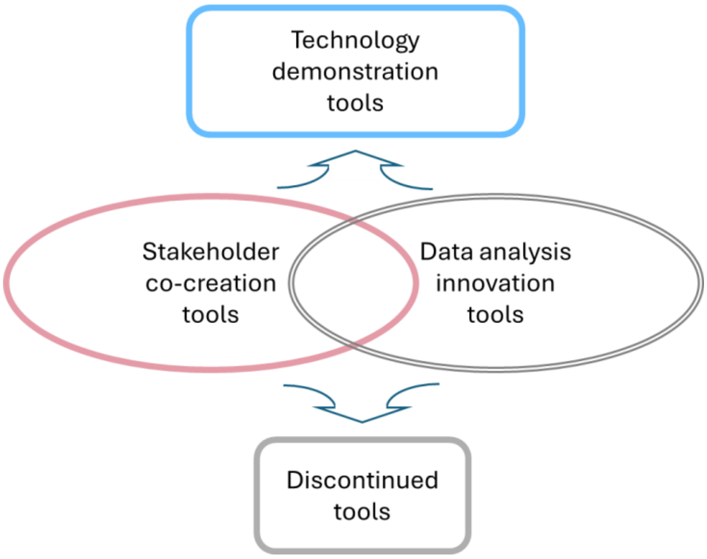


Figure 1. Main groups of tools in the DECIDE project.

Overall, tools prioritized for technology demonstration and tools continued for stakeholder co-creation are at higher TRLs than tools for data analysis innovations. The difference between the first two categories is that the tools prioritized for technology demonstration are seen as showcase tools that require plans for sustainability beyond DECIDE, and a better-defined tool architecture that comes with it. Among tools for stakeholder co-creation, there is variation in the TRL, but some could become showcase tools if we drive for more concrete sustainability plans and reusability.

Tools for data analysis innovation are generally at a lower TRL, without concrete plans for use beyond DECIDE, and, for some of them, the developers are unsure about which development stage they will end up being or even if the tools will be dropped completely. Whether the development will be continued or not is decided together with tool stakeholders (all are in close contact with their stakeholders).

The main conclusions and recommendations for each group of tools for which we plan to continue development follow below.

Tools prioritized for technology demonstration (showcase tools)

- The majority of the showcase tools do not (at least not yet) provide recommendations to make decisions, but they provide information to make them. This could be because 1) the main target are veterinarians or veterinarians together with their farmers and these prefer to get all the information to make their own decisions or their own recommendations, or 2) the preferences of the target users are too diverse to agree on one single type of output, or 3) the processes are too complex or multifactorial to be able to provide a simplified list of recommendations (multiple production factors or business decisions are involved).
- Sustainability of the tool beyond DECIDE has to be strengthened: create metadata and package the tool into an R package or container so the tool can be easily reused.
- Improve tool dissemination beyond traditional research studies: explore journals to publish software and code used to create the project prototypes.
- All the tools are evaluated following the WP3 evaluation framework.

Tools for stakeholder co-creation

- These tools are mainly presenting descriptive statistics, or data filtered by the user. They do not present recommendations to make decisions (see above for showcase tools).
- Push for more concrete sustainability plans. What do they need to make it more sustainable?
- Some additional effort would make tools easy to share and disseminate (reuse): publish them in open repositories, create training material, collate as package, add info about how to use the tool including sample data.
- All the tools are evaluated following the WP3 evaluation framework.

Tools for data analysis innovation

- Evaluation of these tools is not planned because it is too early in their development.
- No clear plans for sustainability beyond DECIDE.
- Unclear how to disseminate the tool (open repository, training materials, sample data, making packages, etc.). However, we will share the progress and code for the solutions we have completed.
- Reasons that the development process stalled:
    - The model did not work as expected
    - No current data flow in place that can be maintained in time, or the type of data does not support the type of models developed
    - Stakeholders were not interested in the tool

2 Summary of workshop on challenges and solutions

2.1 Workshop context

On the 25th of June 2024, the WP3 coordinators (SVA and NVI) organized a workshop to a) document and understand the challenges faced by tool developers in the creation of tools within the scope of DECIDE; and b) identify potential solutions to overcome obstacles to the process and c) foster collaboration between the tool developers. This took place in Nantes during the DECIDE annual general assembly and mainly targeted project participants that have been engaged in the tool development process.

Tool development must be understood as a broad process that encompasses multiple stages (Figure 2), from data acquisition and its management to the evaluation and subsequent updating of the tool. This concept of what constitutes tool development was used throughout the workshop.

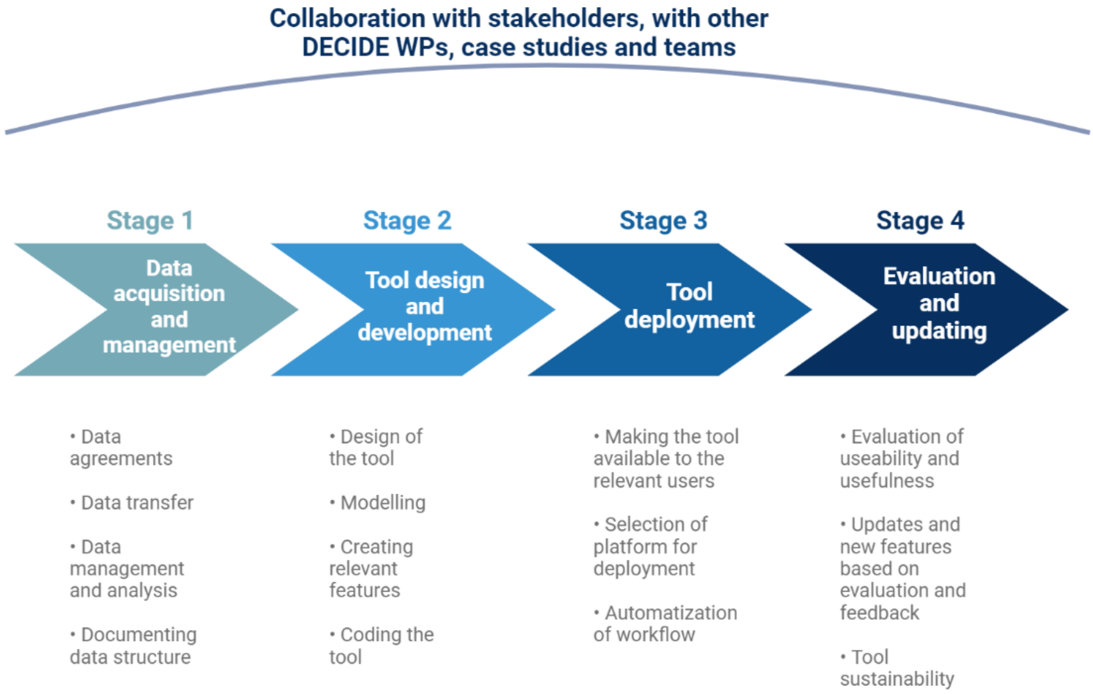


Figure 2. Our understanding of the four stages for tool development process. Activities described under each stage are examples and not a comprehensive list.

2.2 Methods applied

The workshop was conducted as a participatory exercise, followed by open discussions. Participants were asked "What challenges did you and your team encountered during the tool development process?". They identified each individual aspect in a sticky note, and to which stage it corresponded. The stages/aspects considered in this exercise were stages 1 through 3 (Figure 2) and collaboration across WPs, stakeholders and general. Stage 4 of Figure 2 was not considered in this exercise as few groups had reached the evaluation stage.

Following this exercise the moderators (Gema Vidal, Jenny Frössling, Luís Pedro Carmo) worked together with the participants to cluster the sticky notes into common themes. This discussion was used to gain deeper insights into the challenges identified by the participants. Finally, participants discussed how they overcame (or how it would be possible to overcome) certain challenges from the tool development process.

2.3 Results from the workshop

This exercise provided useful insights for the DECIDE project, as well as for the tool development in the context of this project. Some of the conclusions reached during the workshop are well aligned with aspects previously identified by WP3 as relevant in the tool development process.

Detailed results will not be presented in this report, as it is out of scope. However, we present below some overarching themes that emerged from this event:

2.3.1. Tool sustainability

Legal issues remain an obstacle – participants highlighted how difficult it was to put in place data sharing agreements between research institutions and data providers; difficulties in fully understanding legal aspects were also stressed.

Data quality should be improved – data is often not of sufficient quality to perform the analysis necessary to produce the information desired by the users.

Stakeholder engagement is paramount – from data acquisition to the sustainability of the tools, users must be placed in a central role. It is critical to build trust with relevant stakeholders. This should reduce the fear of losing control of data. Adjusting the tool to the user needs, by evaluating and understanding them, will ensure the usefulness of the tool and increase its sustainability. **Stakeholder engagement** is clearly in line with the ethos of DECIDE and is also reflected in the WP3 activities. User involvement was also an important factor to characterize the tools. Furthermore, WP3 developed an evaluation framework (to be applied to users) that will provide helpful insights for further develop the tools. We will also engage with WP5 in the planning and implementation of these activities.

Planning the sustainability of the tool must be done in advance – participants felt that control of the long-term plan for the tool was not always in their hands, which is also reflected in the difficulties of designing a plan for sustainability.

2.3.2. Tool reusability

Metadata is lacking – there is an urgent need to adopt adequate data standards, namely, to create metadata that can help analysts in performing their analyses. This has, so far, been a challenge for several tools and remains an issue for most of them. We plan to collaborate with WP1 in the development of a metadata form that tool developers (at least those working with tools closer to implementation) should provide at the end of the project.

Reusing code is a challenge – tool generalization is difficult for several reasons, namely because of the lack of data standardization across countries/industries and dissimilar information goals.

2.3.3. Other aspects

Collaboration within DECIDE worked well – despite the fruitful collaborations established within DECIDE, it was not always possible to utilize the knowledge generated from every work package in every tool. This is mainly due to the interests of the stakeholders, as there were some aspects they did not find useful to be included in specific tools.

When it came to the discussion of potential solutions for the identified challenges, collaborative projects (within an interdisciplinary or transdisciplinary framework) were highlighted: tool development required a complex toolset that one single individual cannot have. Moreover, it is extremely relevant to engage with users to increase the likelihood that the tools are useful and work in the long run. It was also mentioned that developing business cases for the tools would increase their acceptability.

3 Prototype descriptions – tools prioritized for technology demonstration

3.1 Barometer – Belgium, France, Ireland, Spain, the Netherlands

3.1.1 Context

Bovine respiratory disease (BRD) is one of the most important diseases in cattle, resulting in considerable economic losses, reduced animal welfare, and high antimicrobial use. Awareness of circulating BRD pathogens in a given region combined with early warning systems could support pathogen-oriented decision making, such as preventive measures (e.g., vaccination), enhanced biosecurity, and targeted treatment. Therefore, the idea of the European Veterinary Barometer for BRD was raised by UGent. This tool offers the user a visualization of pathogen-specific laboratory results of respiratory tract samples obtained from all cattle production systems over Europe together with geolocation. In addition to providing an overview of respiratory pathogens in Europe, a further aim is to create awareness about the importance of taking samples.

IRTA aims to develop a swine disease reporting system mirroring the cattle barometer for bovine respiratory diseases developed within DECIDE. The importance of health surveillance cannot be overstated, as it safeguards the health and welfare of animals, the safety of food to consumers, and the quality assurance for trade in pigs and pork products. However, regular pig endemic disease surveillance is limited, and there is still a need to establish off-the-shelf guidelines for disease surveillance at the national level. Through collaboration with multiple Spanish veterinary diagnostic laboratories (VDLs), the goal is to aggregate swine diagnostic data and report it in an intuitive format (i.e., web dashboards). Therefore, this tool offers the user a visualization of pathogen-specific laboratory results over time, of different sample types, and different production stages of pigs throughout Spain. In addition to providing an overview of pig pathogens in Spain, a further aim is again to create awareness about the importance of taking samples and making diagnoses.

The work on the barometer for BRD formed the basis of creating a similar dashboard for broiler production. This dashboard focuses specifically on infectious bronchitis (IB). IB is one of the major viral diseases in European broiler production. Although vaccination has the potential to effectively protect against IB infection, a single vaccine does not protect against all strains of the virus. Information on the most prevalent strains in the region can therefore aid poultry farmers in optimisation of their vaccination strategy. Currently, Royal GD performs monitoring of IB strains in the Netherlands. They publish their results every half year in a magazine and pdf. Farmers and veterinarians could benefit from more regular updates in an easily accessible and interactive dashboard. In this dashboard, additional functions can be incorporated, such as showing results per province and filtering data (for example specifically for broiler chickens). The dashboard can also be adapted to include multiple poultry pathogens, similar to the cattle and pig barometers.

3.1.2 User category/categories

The Pig Barometer is currently open access (Pig barometer – DECIDE Case Studies (decide-project-eu.github.io), and the European cattle barometer (https://decide-project-eu.github.io/case-studies-website/case-studies/cattle-barometer.html) will be open access by the end of the DECIDE project. A pilot of the poultry barometer with historical data (2018-2022) is available on the DECIDE website as well (https://decide-project-eu.github.io/case-studies-website/case-studies/poultry-barometer.html). As an open access tool, it is available to a wide variety of users (veterinarians, VDLs (data providers), farmers, technical/health advisors, researchers, etc.). When the barometer is used by specific laboratories with their own data, they could decide to have different levels of access, depending on the sensitivity of the data.

3.1.3 Data source

The cattle data owners are the collaborating laboratories from Belgium (DGZ, ARSIA, PathoSense), the Netherlands (Royal GD), France (Labocéa) and Ireland (Department of Agriculture, Food, and the Marine). Their data consists of laboratory results (pathogen identification of respiratory tract samples), geographical data, production type, and if available, herd characteristics at the discretion of the data provider.

The Pig Barometer is being developed to share retrospective and prospective surveillance information derived from submissions to participant VDLs from Spain. The data owners are collaborating laboratories from Spain (i.e., Exopol, Hipra, Labopat, Convet, Zootecnia, and Biofar). Their data consists of pathogen-specific laboratory results aggregated by an anonymous case ID, date, sample type, geographical data, herd characteristics and/or productive stage.

The poultry barometer only uses data from Royal GD. The dashboard is based on PCR results from IB monitoring. The farm identification in this dataset is used to link the result to a province in the Netherlands, using the Poultry Monitoring Program, also managed by GD.

3.1.4 Tool architecture

At UGent the data from the different laboratories are processed (cleaned and formatted) using R and Python software to create RDM files which are combined into one file. The poultry data are processed differently: these are sent to UU as an Excel file. The data are subsequently processed using the online platform Databricks, which involves cleaning, linking farms to provinces, and aggregating at quarter and province level. The resulting dataset is saved as a csv file.

For all species dashboards, the files (RDM or csv) are implemented in Tableau for visualization. Ontologies are being created in collaboration with WP1 to facilitate data interoperability. The Tableau dashboard is hosted on a secure Azure website, which is now open access and connected to the DECIDE website.

Long-term solutions for data pipelines, software solutions and IT infrastructure are yet to be identified and will be implemented depending on users' technical requirements and capabilities of the hosting institution. For example, the poultry barometer could be hosted by GD; however, if data from other labs would be added, then new solutions for sustainable up-to-date data sharing should be explored.

3.1.5 User interface

Figure 3 shows a screenshot of the actual (pilot) dashboard to illustrate the components and connections. The default settings show an overview of all the positive cases by pathogen from all laboratories (A). Per individual pathogens, distribution of positive cases over time (month/year) can be visualized (B). This is also possible per geolocation (C), per sample type (e.g., swabs, bronchoalveolar lavages, tissue) (D), per used diagnostic test (just PCR at the moment) (E), and the production stage from which the sample was obtained (e.g., nursery, fattening) (F). It is possible to change between count and proportion (%) of positive cases for all measurements (G). In addition, one can filter based on interest (e.g., province, diagnostic sample, production type).

The features of the poultry barometer are adapted to its main goal to aid decision-making on vaccination strategies. To keep the tool as simple and comprehensible as possible, only tool components that contribute to this goal are included. Figure 4 shows the dashboard, in which the presence of different IB strains in each quarter of the year and province of the Netherlands are shown.

Currently, Tableau is being used for the interface and is openly accessible to the users through the DECIDE website. If laboratories decide to use the barometer for their own website, it is possible that login requirements are added. The frequency of updates is yet to be determined and will be done in consultation with the individual laboratories. The goal is to have a continuous updating system. A screenshot of the user interface is provided under the section below (Figure 4).

Although the goal is to have an open access tool, future accessibility to the tool will depend on the identified long-term hosting solution. At this time, no concrete plans for its future implementation have been established.

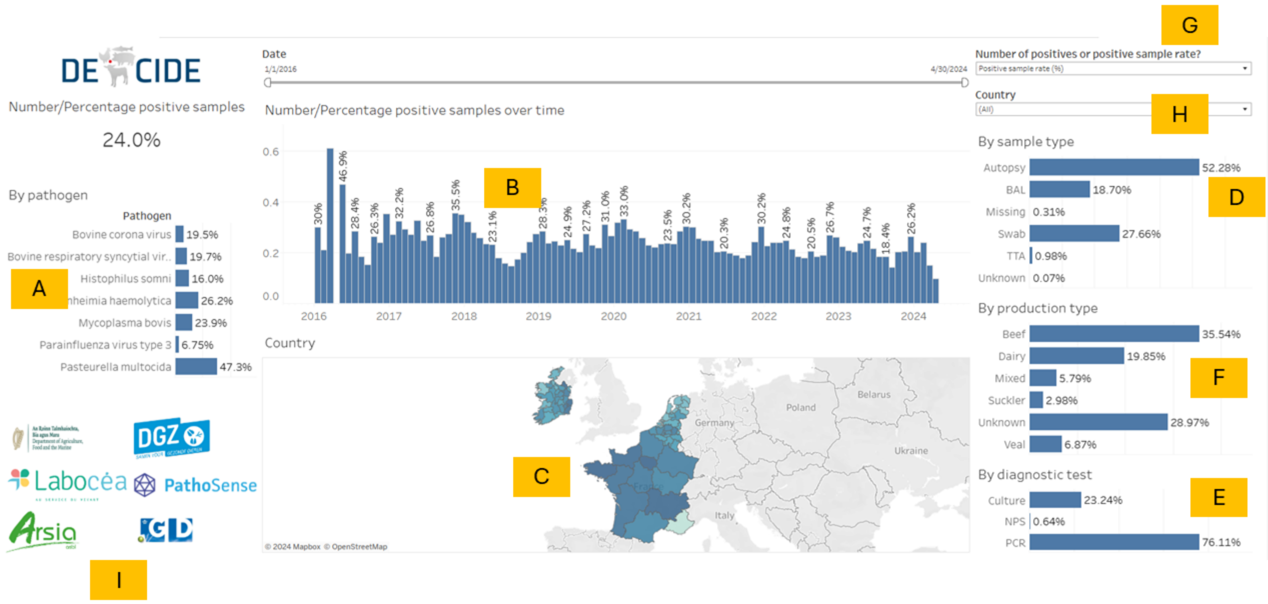


Figure 3. Screenshot of the European Veterinary Cattle Barometer, developed by UGent. A) The different pathogens involved, B) distribution of specific pathogens over time (month and year), C) per province, D) per sample type, E) per diagnostic test, and F) the production type. Results can be shown as either count or proportion of positive samples (G), and per country (H). Logos of collaborating companies are shown (I).

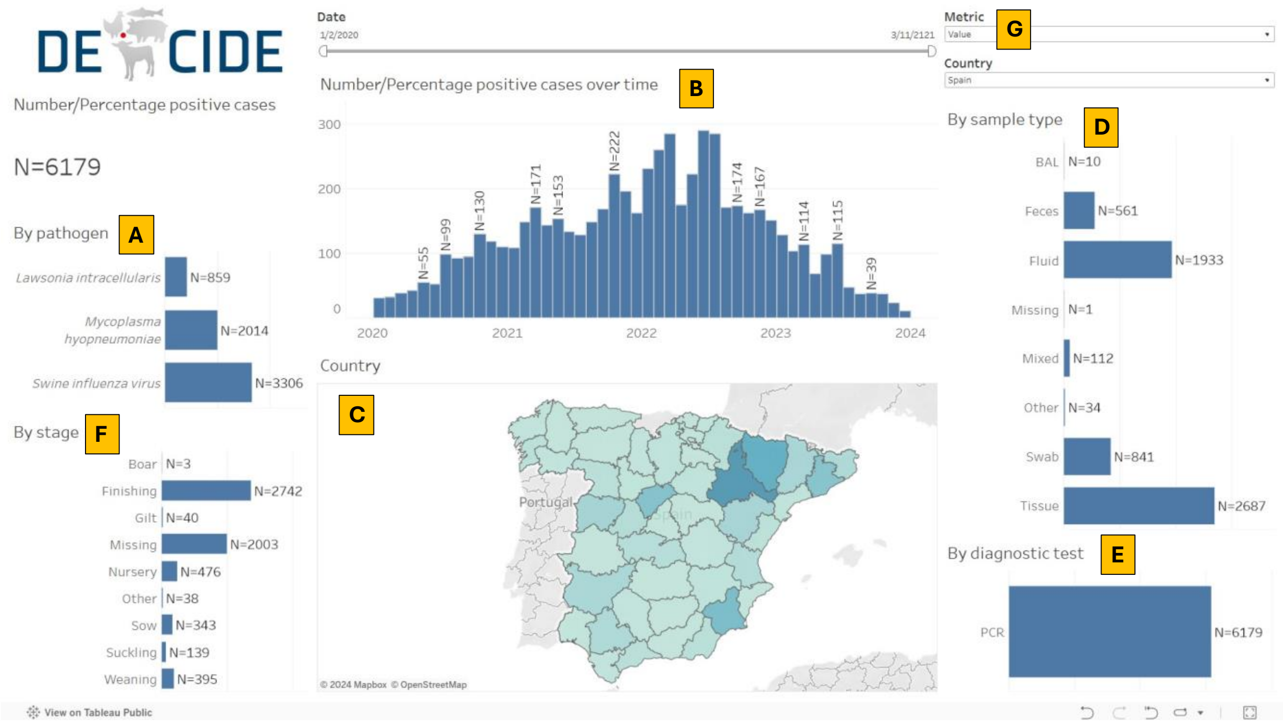


Figure 4. Screenshot of the Pig Barometer, developed by IRTA and UGent. A) The different pathogens involved, B) distribution of specific pathogens over time (month and year), C) per province, D) per sample type, E) per diagnostic test, and F) the production stage. Results can be shown as either count or proportion of positive samples (G). Logos of collaborating companies are not yet included.

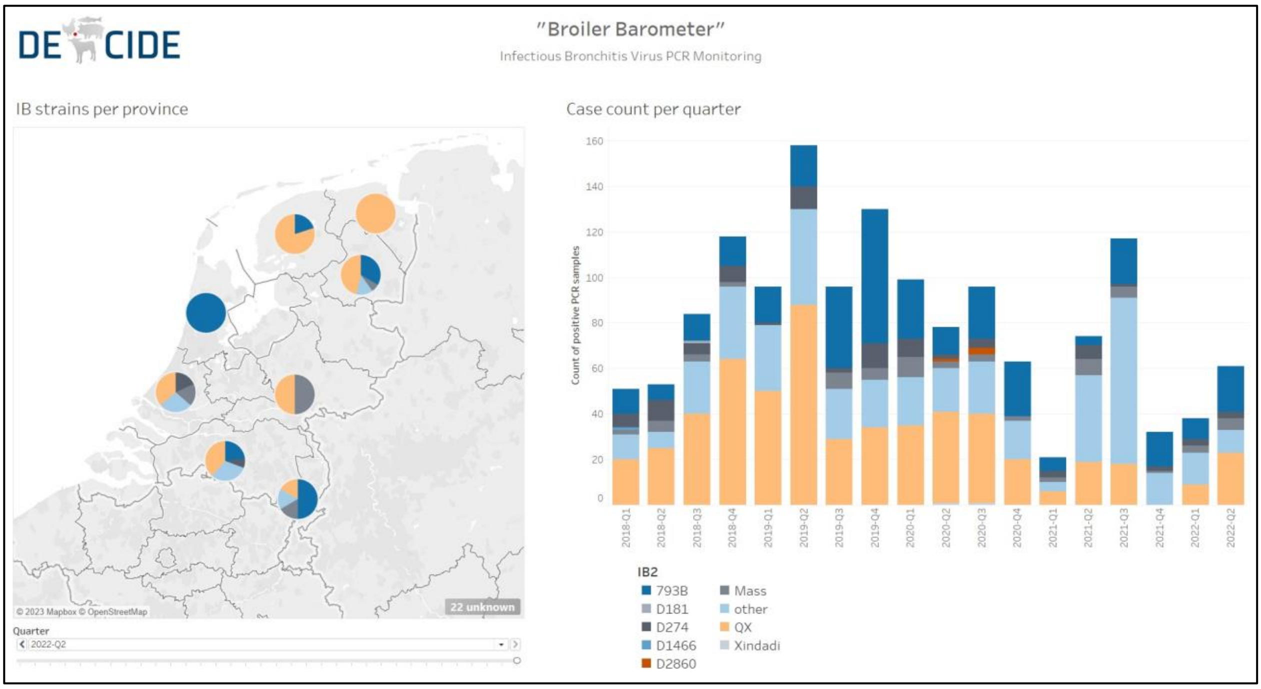


Figure 5. Screenshot of the poultry barometer, developed by UU.

3.1.6 Content and functions

Figure 3 shows a screenshot of the European Veterinary Cattle Barometer dashboard. The default settings show an overview of all the identified pathogens associated with BRD from all laboratories (A). For individual pathogens, a specific-pathogen distribution over time (month/year) can be visualized (B). This is also possible per geolocation (C), per used sample type (swabs, bronchoalveolar lavages, necropsy, etc.) (D), per used diagnostic test (PCR, culture or nanopore sequencing) (E), and the production type from which the sample was obtained (beef, dairy, veal, mixed, etc.) (F). It is possible to change between count and proportion of positive samples for all measurements (G) or per country (H). In addition, one can filter based on interest (e.g. province, diagnostic sample, production type). The logos of the collaborating companies are shown (I), and when clicking on the logos one will be directed to the company website. Veterinarians and farmers can use the information for on-farm decision-making to control BRD (vaccination, purchase support, etc.).

The dashboard for the Pig Barometer is being designed to visualize pathogen-specific laboratory results gathered from submissions to Spanish VDLs. We have started with a pilot (prototype – first version) dashboard showing the information of three swine pathogens of relevance; two respiratory pathogens (*Mycoplasma hyopneumoniae* and swine influenza virus) and one digestive pathogen (*Lawsonia intracellularis*). Thus far, we have included information for three years, from 2020 to 2023. This pilot dashboard is being used as proof-of-concept for: (1) signature of data transfer agreements (DTA) with participating VDLs, (2) dataflow and pipeline (including definition of ontologies), and (3) data visualization. While thus far the pig barometer is using the content and functionality of the cattle barometer, examples of existing pig disease surveillance dashboards from other countries exists: the Great Britain disease surveillance dashboards (http://apha.defra.gov.uk/vet-gateway/surveillance/scanning/disease-dashboards.htm) and the United States Swine Disease Detection Dashboards (https://fieldepi.research.cvm.iastate.edu/domestic-swine-disease-monitoring-program/). Both of them will be considered in the development of the Pig Barometer. The next version of the tool is yet to be defined, but it will probably include more swine pathogens, different visualization settings, and the logo of the collaborating VDLs. The frequency of updates is yet to be determined and will be in consultation with the laboratories, although the ultimate goal is to have a continuously updating system.

The most important output from the poultry barometer is the proportion of samples belonging to each IB strain per time step (quarter). This information can help to choose an optimal vaccination scheme. The dashboard map of the Netherlands includes a slide to show historical data. One province can be selected to show the number of strains through time for this province only. Currently, only broiler data is included, but it makes sense to include laying hen data as well. An additional filter could be added to filter on type of chicken.

3.1.7 Involvement of WPs

For the Cattle barometer, a collaboration with WP1 was done for creation of the ontologies, data processing and automate of the data flow. Further, a collaboration with WP3 explored the integration of Early waring into the Cattle barometer platform, and a potential collaboration with partners from WP4 was explored, but the barometer was concluded not to be the most accessible tool to integrate economic information/models.

For the poultry barometer, an ontology was created for data on infectious bronchitis PCR samples in collaboration with WP1.

3.1.8 Sustainability aspects

Several contributors have emphasized the value of continuing the Cattle Barometer, though no concrete plans for its future implementation have been established. The code is open access available for all interested parties to use and display their data. The idea of keeping a European barometer website and was generally warmly welcomed, but sustainable financial support needs to be provided. EFSA, EMA and FVE were contacted for this purpose.

There are no specific plans for the sustainability of the Pig Barometer. However, our ambition is that IRTA (together with the participating VDLs – data providers) will host the tool beyond the DECIDE project.

For the poultry barometer there are also no specific plans yet for sustainability after the DECIDE project. The data is already collected by Royal GD, which makes hosting of the tool by Royal GD achievable in the remainder of the DECIDE project. As mentioned before, data from other labs in the Netherlands could be added, which would increase the added value of the tool compared to the present publication of the data. To achieve this, new solutions for sustainable up-to-date data sharing have to be investigated. Currently there is no contact with other labs.

3.1.9 Plan for the remainder of the project

For the Cattle barometer, the results from a user-usability survey will be used to further enhance the tool. Meanwhile, different EU labs will be contacted for potential collaboration, and methods for continuation of the tool will be explored.

- December 2024: finish user survey rounds for the Cattle barometer in different EU countries
- January 2025 – May 2025: adjust the tool based on the evaluation
- Nov 2024- Oct 2026: exploring possibilities for continuation of the tool after the project ends
- Nov 2024- Oct 2026: introducing the tool to labs in different EU countries to expand the tool
- Next version of the Pig Barometer (foreseen by fall 2025) will be discussed once the first evaluation is finished (foreseen by winter 2025). Based on the results of the tool evaluation, the content, functionality, and interface will be modified if needed. Thereafter, dissemination of results to users through IRTA's communication channels, and specific congresses/meetings/workshops is expected. Winter 2024-2025: first evaluation round in Spain.
- Spring 2025: define objectives for next development round.
- Summer 2025: adjust the tool based on evaluation.
- Fall 2025: finish tool documentation, work on all the necessary information to make the tool available in the GitHub repository.

Throughout 2025: dissemination of results to scientific communities and the Spanish pig sector. We plan to evaluate the usefulness of the poultry barometer with clients from GD, by sending them an email or several emails with up-to-date IB monitoring information. This is planned for spring 2025. Furthermore, we will discuss tool sustainability within GD. We will test whether the API that GD is developing for the Cattle Barometer is useful in our data pipeline. Lastly, we aim to contact other diagnostic labs in the Netherlands to determine their interest in the tool. After discussion with project members, especially SLW Biolab, we chose not to expand the tool to other countries because of differences in diagnostic tests.

3.2 BRD Tools (Eval’BRD, Connect’BRD) – France

3.2.1 Context

Bovine Respiratory Disease is a major health issue in young beef cattle, especially in fattening farms where it can affect a large proportion of weaned calves in the first weeks after arrival. The diversity of pathogens involved (bacteria and viruses), leading to various clinical signs (mild or severe), makes BRD difficult to prevent, detect and treat, often leading to high antimicrobial usage. A mechanistic BRD model has been developed at INRAE to account for three different pathogens, risk levels and between-pens/between-building transmission. We intend to provide a web tool prototype based on this model to help farmers or veterinarians to better anticipate the risk of BRD outbreak in their farms in contrasting scenarios, and to compare and **rank intervention strategies** (“Eval’BRD”). In addition, we aim at developing a method for connecting this tool with real-time on-farm sensor data to implement **early detection** of BRD cases and associated intervention ranking (“Connect’BRD”).

3.2.2 User category/categories

Cattle farmers, veterinarians, farm advisors.

3.2.3 Data source

Both BRD tools use input from the users (composition of batches in the farm, risk levels, major pathogens, etc.) to describe the specificities of their situation of interest. These inputs are combined with other information such as parameter values involved in the model or predefined detection/intervention strategies, coming from observation data (temperature, clinical data, laboratory data), non-observable values estimated from observation data, existing knowledge, literature, or expert advice/assumptions.

In addition, Connect’BRD also relies upon sensor data (time spent on several activities and health index) coming from commercial accelerometer collars to assess the individual health status of calves and update the situation in the mechanistic model.

3.2.4 Tool architecture (including figure)

The tool relies upon a mechanistic model developed with EMULSION (open-source framework), and the tool software itself is generated through the PASTE software (also open-source), based on the model and structured text specifications expressing the users' needs — see Figure 6. The tool can be updated periodically to make features evolve according to user feedback, or to reflect evolutions in the underlying model (regenerating the tool from the model is an automatic process). If users require more specific adaptations of the tool or of the underlying model, they will need to be trained to use PASTE or EMULSION.

Eval’BRD will be a web application based on Python/Django running on a web server and interacting with EMULSION, Celery, Redis and Rshiny installed on a calculation server (Figure 7). During development it can be tested on an internal server or on a local machine. It will require a dedicated server to make it usable from outside. The web server and the calculation server can run on the same physical machine If needed. At this stage we do not anticipate login requirements as users do not have to store any personal information on the tool.

In addition, Connect’BRD will incorporate a process to retrieve sensor data, estimate the health status of the calves through a trained machine learning model, and request new simulations if changes are detected. Based on the comparison of scenario outputs, a new intervention ranking can be produced, and users can be notified about recommended interventions (Figure 8). In Connect'BRD, sensor data are farm-dependent and will thus require user accounts, including personal data to send the notifications.

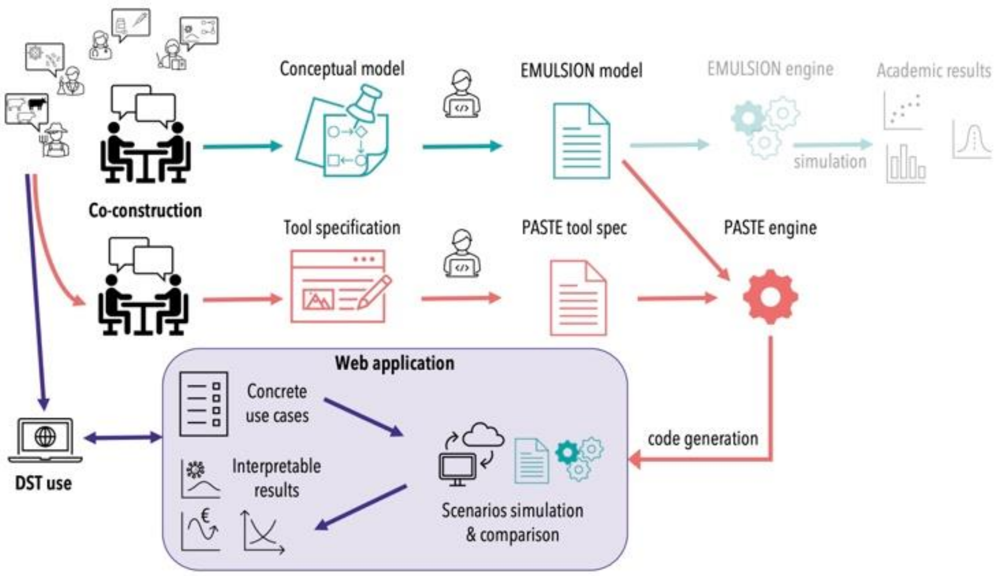


Figure 6. Web tool generation by the PASTE software, based on an EMULSION model and textual tool specifications (principles to build Eval'BRD).

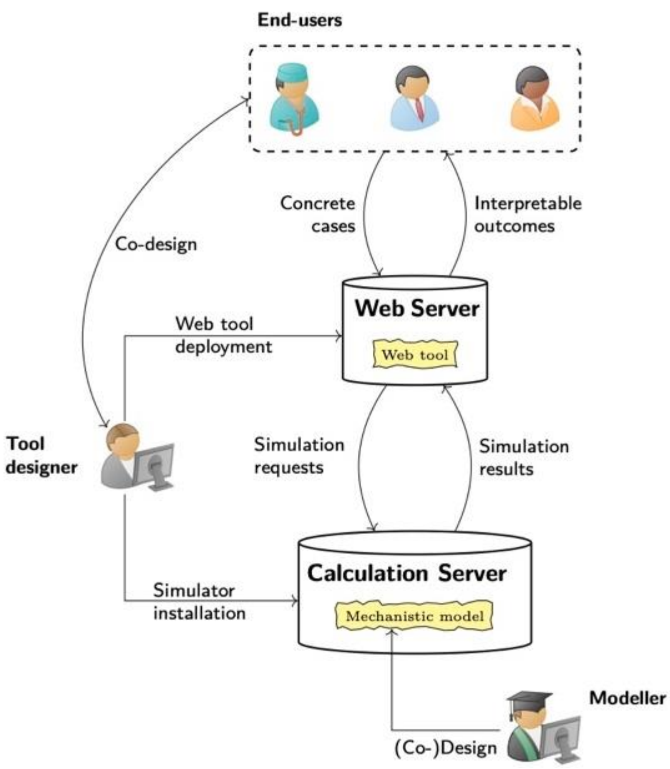


Figure 7. Architecture for the deployment and usage of Eval'BRD.

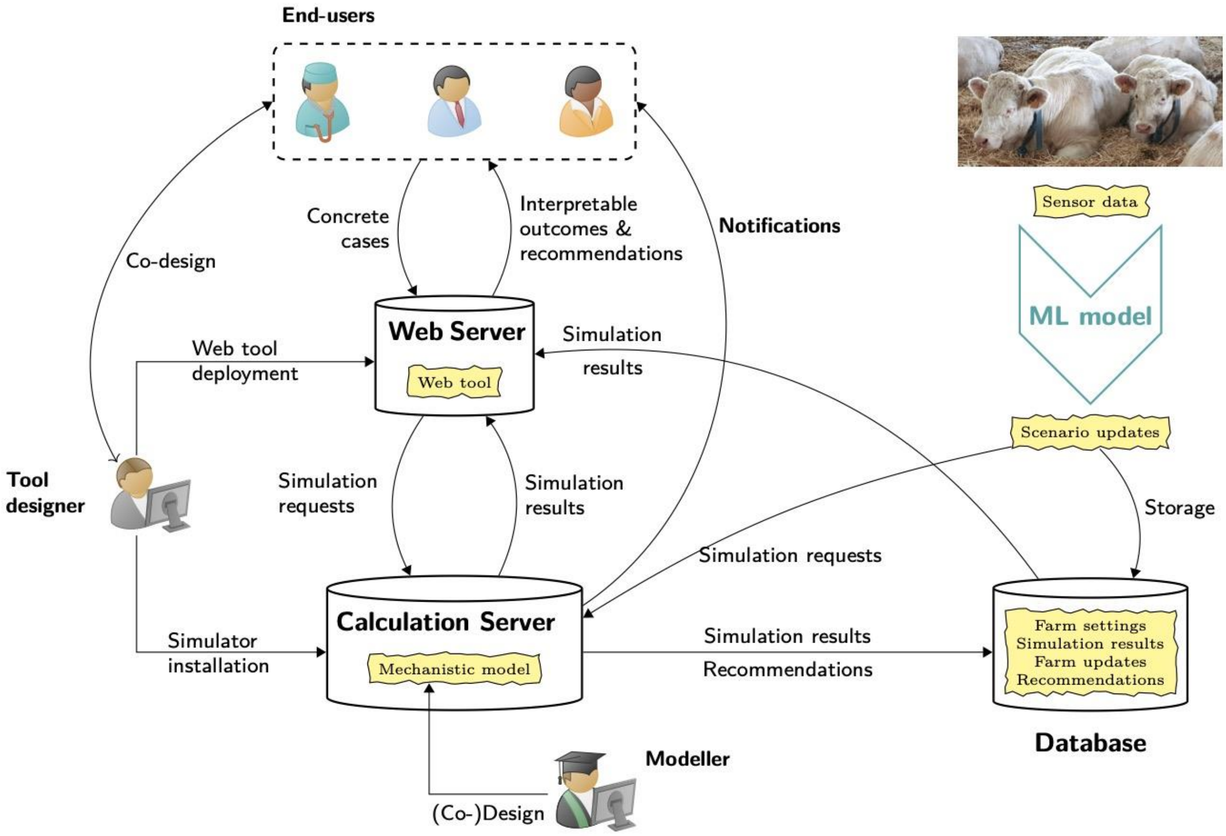


Figure 8. Architecture of Connect'BRD. A trained machine learning model updates the scenarios of the mechanistic model to trigger new simulations and notify the users when new interventions are recommended.

3.2.5 User interface

The user interface consists of several input forms enabling the user to specify farming conditions (e.g. number of batches, batch size, risk levels of calves regarding BRD) and economic variables (such as costs and revenues related to production or disease impact) — see Figure 9, to choose intervention scenarios to compare (Figure 10). After launching the simulations, results are displayed on several pages, to allow for scenario comparison at various scales and according to complementary points of view, e.g. at batch scale (Figure 11), farm scale (Figure 12), or cost/benefit analysis (Figure 13).

In Connect'BRD, the input forms and output pages are the same, but they are not directly connected. Instead, inputs from the forms are stored in a database, and output pages are produced when the system identifies an evolution in the health status of the batches. The users can access output pages at any moment but will also receive notifications if interventions are recommended.

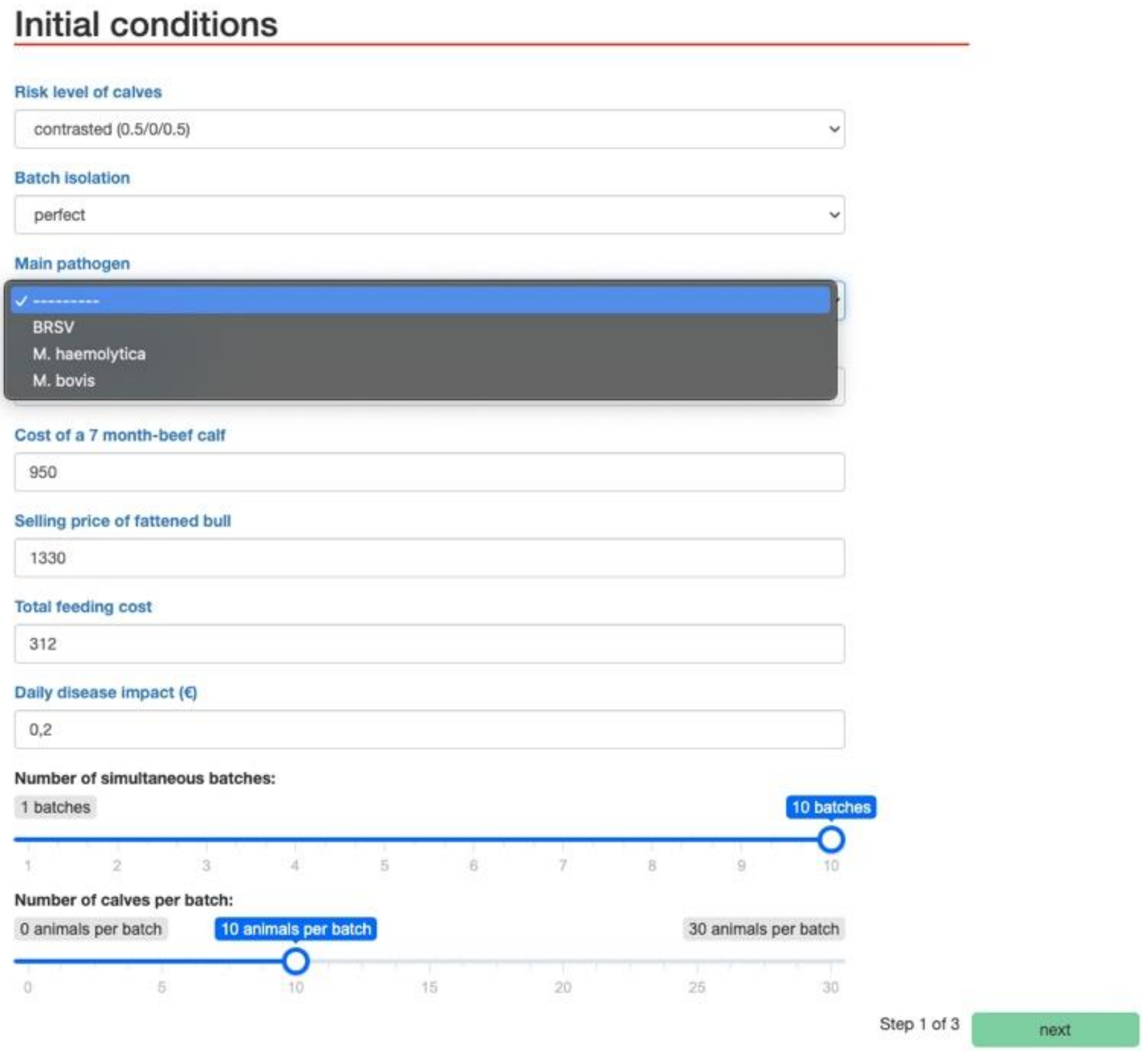


Figure 9. Input form for initial conditions in the farm.

Figure 10. Input form for scenario selection (here, impact of the disease whether calves are affected into batches randomly or depending on their risk level regarding BRD).

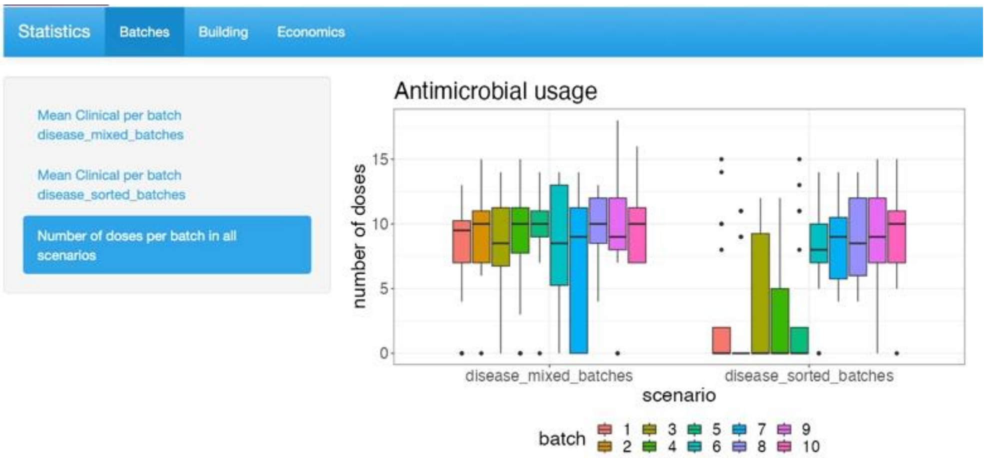


Figure 11. Antimicrobial usage at batch scale, depending on the batch allocation scenario.

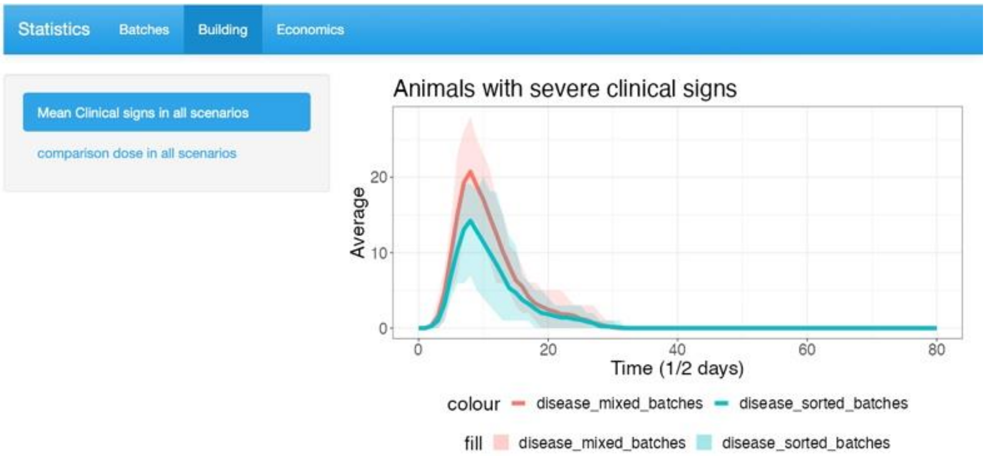


Figure 12. BRD cases over time depending on the batch allocation scenario.

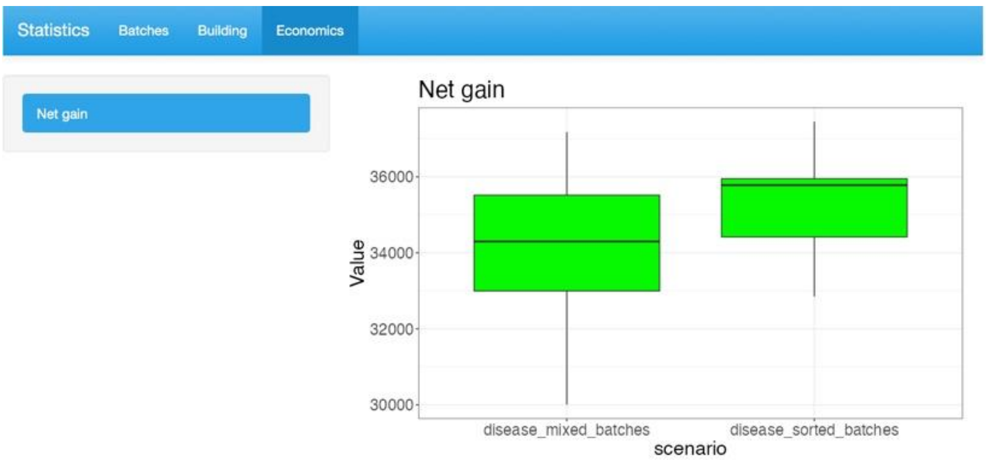


Figure 13. Estimation of the economic gain, depending on the batch allocation scenario.

3.2.6 Content and functions

The model underlying the tool involves individual animals as epidemiological units and provides representations at different group levels (batch, building, region), with a time scale in half-days. The tool can be run at will to assess specific farm situations, and it can be updated in real time or periodically (e.g., every 2-3 months) depending on the needs.

Both tools will ask the user to define parameter values for adapting to his/her specific concerns, then the intervention strategies to compare. The tools will then run several stochastic repetitions for each scenario, build a synthetic graphical report to inform the user on predicted trends, and provide a ranking of envisaged interventions.

In addition, Connect'BRD will send notifications to users if the intervention ranking leads to new recommendations.

3.2.7 Involvement of WPs

Both BRD tools are based on mechanistic models of Bovine Respiratory Diseases. Hence, they are strongly connected to WP2 (modelling). First, the model currently used in eval'BRD is the latest one developed by Baptiste Sorin in his PhD thesis, incorporating multiple batches for each farm, accounting for the co-circulation of a virus (BRSV) and a bacteria (*M. haemolytica*) and for vaccinal strategies. Second, the model used in connect'BRD is a mix between the model introduced in Baptiste's first publication (PVM, 2023) and more recent work on triggering collective treatment: a paper submitted to PCI Animal Science, and another one resulting from a within-WP2 collaboration with Carolina Merca (UCPH). We also organized several workshops in WP2/WP3 to incite our colleagues to develop a model and sketch a tool based on it for their own concerns. This resulted in the development of a model for *M. hyopneumoniae* in pigs (with Beatriz Garcia-Morante, IRTA, and Marloes Boeters, U. Utrecht), which could eventually lead to a tool similar to eval'BRD.

More recently we worked together with WP4 to incorporate cost and benefits in the tools (done currently in eval'BRD), and also anticipate the adaptation of the model and tool to veal calves (in Belgium) and to incorporate welfare issues. WP5 is also involved, mainly through the collaboration with Idele, to discuss with stakeholders (farmers, cooperatives, veterinarians), set up the focus groups and qualitative surveys, and provide feedback to farmers and cooperatives. So far, the connection with WP1 is the weakest, as the BRD tools are the ones that rely the least on data. However, we believe that using formalisms such as ontologies could help adapt the tools to other diseases / production systems / countries (but not alone, as this primarily requires to adapt the underlying models), so we consider investigating this in the coming year.

3.2.8 Sustainability aspects

The sustainability of the BRD tools will rely on several points. First, as we are mainly focused on developing methods, we aim at reusability and adaptation. This is ensured by releasing all software frameworks (EMULSION and PASTE) and all mechanistic models (several for BRD, soon also for *M. hyopneumoniae*) as open-source code, but also by opening training workshops on these methods. Second, INRAE servers will host Eval'BRD, which can be open freely to a broad range of users. For Connect'BRD, sustainability will depend on the willingness of farmers, cooperatives and the sensors' manufacturer to continue beyond ongoing research projects.

3.2.9 Plan for the remainder of the project

Eval'BRD is almost finished, its parameters can be improved based on collaborations with WP4. The underlying mechanistic model (developed in WP2) should be adapted to veal calves farms in Belgium, enabling for the development of a similar intervention ranking web application in this context. We also plan to discuss how to account for animal welfare in the BRD model or in the BRD tools.

We intend to test Connect'BRD from December 2024 to June 2025. Nine fattening farms near Nantes will participate in the assessment of the efficacy of the tool compared to usual farming practices and to the commercial device alone. Idele will also carry out qualitative surveys and focus groups with farmers, veterinarians and cooperatives to assess the suitability and acceptability of the tools.

The documentation of the BRD tools is not finalized yet, as we expect to improve it based on the users' feedback.

Dissemination will be ensured through research publications but also through communication in the sector's events.

3.3 Abattoir Inspect – Scotland

3.3.1 Context

Analysing livestock condemnation data from abattoirs is essential for improving herd health management and ensuring food safety. These data provide critical insights into the prevalence of diseases, injuries, and other health conditions that may not be evident on the farm but are detected at slaughter. By reviewing the reasons for condemnation, such as infections, parasites, or physical defects, we can identify emerging health threats, refine biosecurity protocols, and enhance animal welfare practices. Additionally, analysing trends over time helps in the early detection of zoonotic diseases, ensuring public health is protected, and can inform targeted interventions to reduce economic losses for farmers by addressing preventable conditions.

Scotland has a highly specialised, innovative, and concentrated pig farming sector. About 150 holdings keep 98% of the breeding sows. Farms are concentrated in the Northeast, where 60% of breeding sows and fattening pigs are kept. The pig sector generates around 3% of Scottish agricultural input and around 24,000 tons of pig meat are produced in Scotland every year. Processing of these pigs is also highly concentrated in a few abattoirs (the main one processes about 90% of all pigs in Scotland), which makes this step of the production chain ideal to carry out actions to improve animal health and welfare and the quality of the sector. Further, because of its concentration in a small number of farms, the sector is highly organised and best placed to develop, test, and implement tools such as the one described below.

3.3.2 User category/categories

This tool has potential to be used by multiple users such as Scottish pig industry representatives; farmers; veterinarians, national authorities; and anyone else interested in analysing meat inspection data. Currently, there is only one user profile for all, but we plan to develop different user profiles which would have access to outputs tailored to their needs and understanding. This would also allow to control data confidentiality and sensitivity issues.

3.3.3 Data source

The data used to generate and initially populate this app was sourced from one large abattoir in Scotland and it corresponds to meat inspection outcomes as issued by the national authority – Food Standards Scotland (FSS). We have created a mock dataset based on the original data which now is shown on the app. The app can also be used to visualise user-uploaded data.

3.3.4 Tool architecture

The complete flow diagram is shown in Figure 14, outlining how data is sourced, processed and presented in the Abattoir Inspect app. Data for the system comes from three primary sources:

- Food Standards Scotland (FSS): Real data is provided in CSV format.
- User-uploaded data: Users can upload their own CSV files containing abattoir condemnation data via a user-friendly interface.
- Mock dataset: A pre-integrated mock dataset is available for users who prefer not to upload their data.

All data is ingested through a dedicated layer that performs initial checks to ensure proper formatting and compliance with predefined criteria. Once validated, data is stored in a PostgreSQL database, enabling efficient querying and retrieval. User-uploaded data bypasses the database and is handled temporarily during the session, ensuring privacy by deleting the data when the session ends.

Data processing occurs in an RStudio environment, where data cleaning, transformation, and feature engineering are carried out. R scripts manage these processes, using SQL queries to fetch FSS data from the database and handling user-uploaded data directly.

The development of the application followed a collaborative and iterative approach. A multidisciplinary team of data scientists, epidemiologists, and veterinarians have worked together to plan the application, to ensure it meets the needs of both technical and industry stakeholders, especially those handling these kinds of data on a daily basis. Stakeholder feedback will inform the app's design and refinement, addressing specific requirements, challenges in inspection processes, and alignment with industry standards and expectations.

The app is built using R Shiny (an open-source resource), with a focus on user-friendly interface design. Throughout development, the source code is managed on GitLab, with version control and continuous integration ensuring code quality and functionality. A Docker image encapsulates the application and its dependencies, enabling consistent deployment across environments, including local machines, cloud servers, and container platforms like ShinyProxy.

The app is then deployed using ShinyProxy, an open-source platform that manages user sessions, scales the app, and facilitates seamless access. Users interact with the app through a web browser, engaging with features designed to streamline abattoir data analysis.

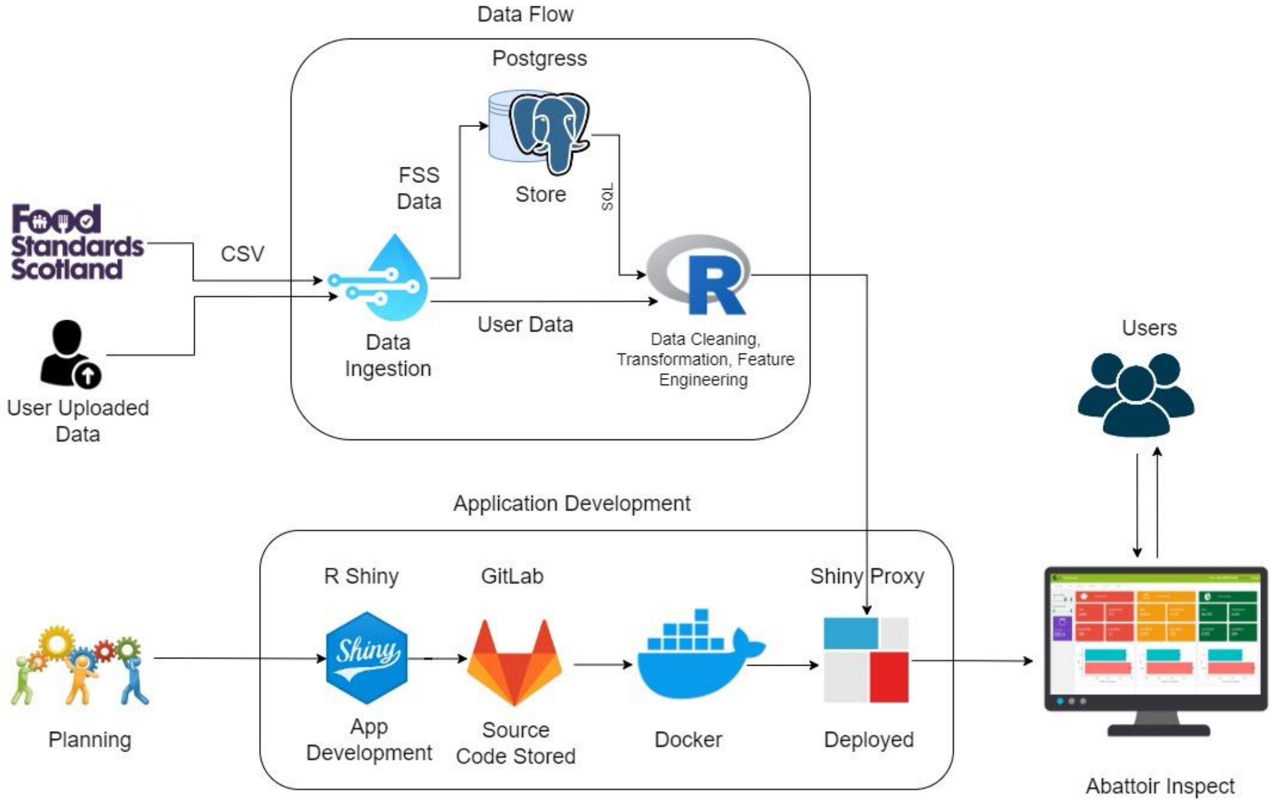


Figure 14. Flow Diagram of the Abattoir Inspect development stages.

3.3.5 User interface

The dashboard is designed in R shiny and is publicly accessible.

3.3.6 Content and functions

The Abattoir Inspect tool provides an intuitive platform for analysing abattoir data, offering valuable insights into livestock health, welfare, and operational performance. The interface is intuitive, and it contains three specialised tabs: Basic, Advanced and Time Series. This allows new and experienced users to make the most of different functions. It enables detailed profiling of abattoir condemnations and supports custom data exploration with advanced filters. Users can focus on specific parameters, such as farm or producer-level analysis, identify bottom-performing farms and producers, and benchmark performance across the industry. Clear, visually intuitive charts make complex data easier to understand.

The tool includes dynamic time series analysis, allowing interactive visualisation of temporal trends to identify patterns and long-term changes for each meat inspection outcome. An intelligent alert system uses a triple-algorithm approach for real-time anomaly detection, with early warning thresholds guided by expert input. These thresholds can be customised in future versions. Users can evaluate the system's performance using metrics like precision, recall, and accuracy, along with detailed breakdowns of true and false positives and negatives.

Initially designed for pig data, the tool's architecture allows adaptation to other livestock species, making it scalable for various agricultural contexts. Users can download detailed CSV reports containing dates, producer information, and detected alerts. A comprehensive mock dataset with over 200,000 entries is included, based on real data, to showcase its capabilities. Users can also upload their own data in CSV format for personalised analysis, with the assurance that no uploaded data is retained by the system.

The tool is available in two versions. The stakeholder version, restricted to authorised users, uses real data for detailed analysis. The public version, accessible worldwide, includes mock data and allows users to upload their own datasets for free via https://epidemiology.sruc.ac.uk/shiny/apps/testing/abattoir_inspect/.

Comprehensive support ensures ease of use, including FAQs, a contact form, and access to SRUC veterinary services for expert advice. Technical support is available from the development team, and a video tutorial will soon be added to guide users through its features.

Overall, this platform empowers stakeholders to make data-driven decisions, enhance operational efficiency, and maintain the highest standards of food safety and animal welfare.

Figure 15 presents key statistics on condemnations for 2020-2021 using the mock dataset. The dashboard is strategically divided into three sections (Basic, Advanced, and time series), offering a clear breakdown of the total figures as well as the statistics for the last quarter, month, and week for full, partial, and total condemnations. Each section features bar plots illustrating the annual condemnation counts across all three categories, providing a comprehensive and easily digestible view of the data.

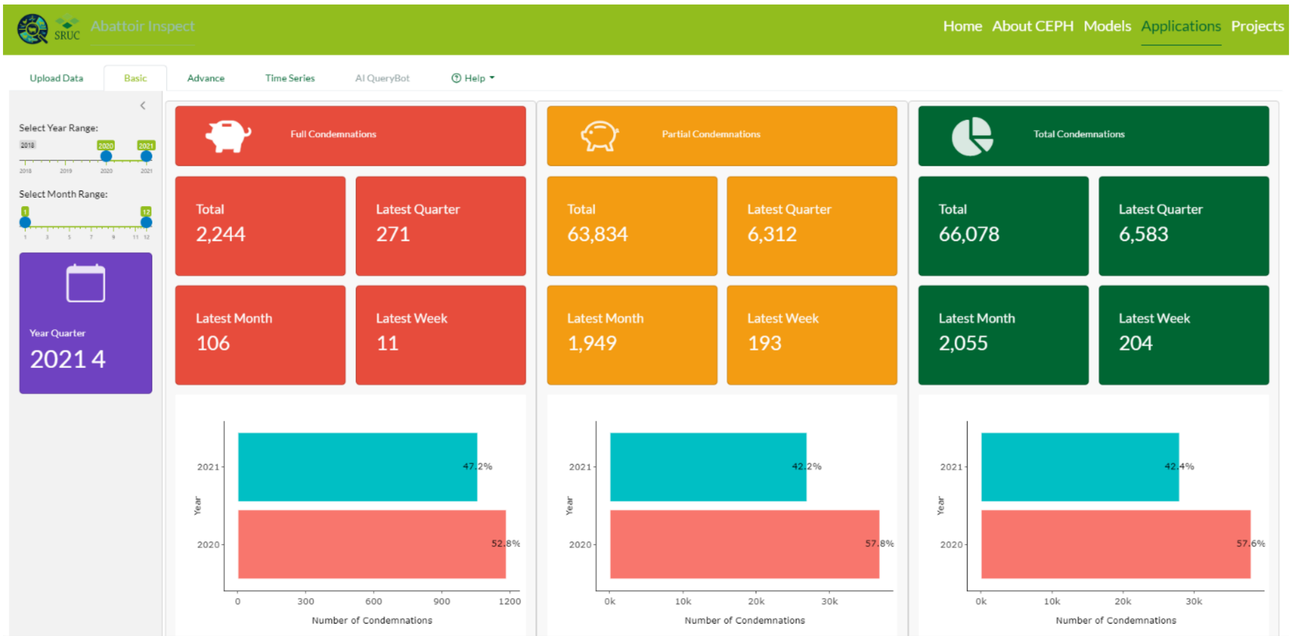


Figure 15. Key condemnation statistics for 2020 - 2021 with mock data set.

Figure 16 displays two plots: the first illustrates the number of full condemnations, while the second focuses on partial condemnations. Each plot highlights the conditions associated with the respective types of condemnations, clearly showcasing the relationship between these conditions and the number of condemnations recorded.

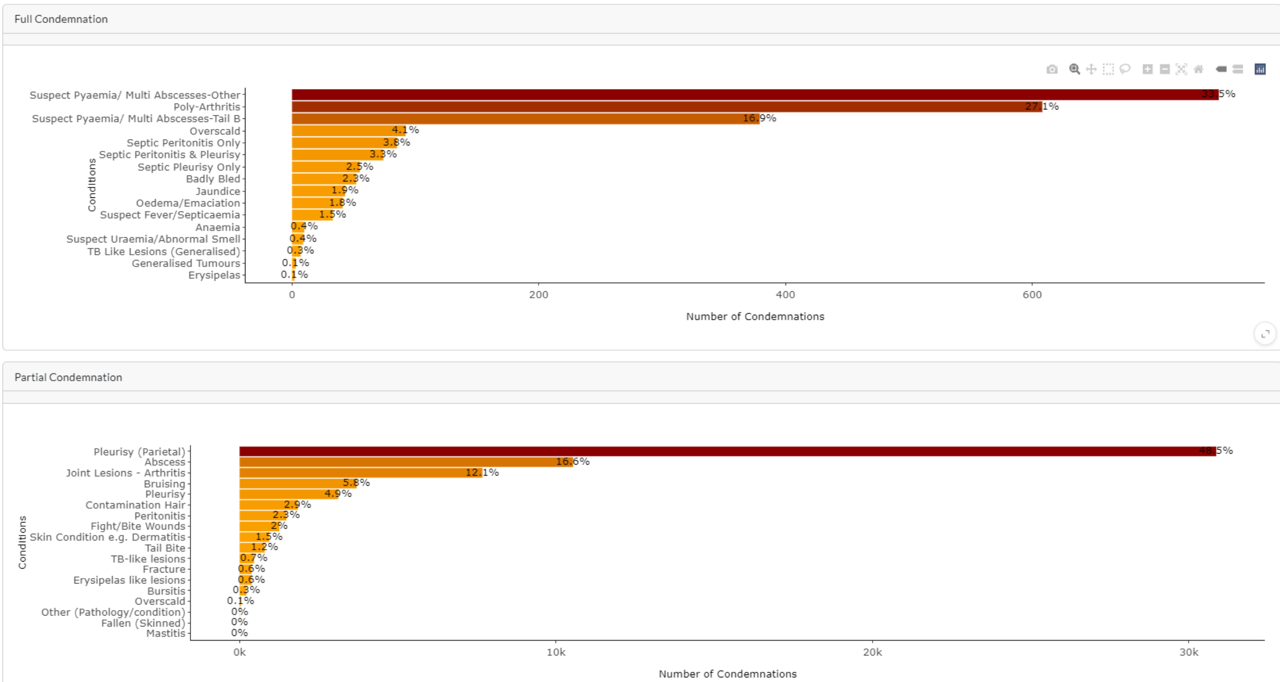


Figure 16. Breakdown of the most to least common reasons for full and partial pig condemnations, respectively (mock dataset).

Figure 17 presents a benchmark analysis of selected farms, illustrating their performance across the top five conditions. This figure provides a comparative view, highlighting how each farm measures up in relation to these key conditions, enabling quick identification of performance trends and areas for improvement.

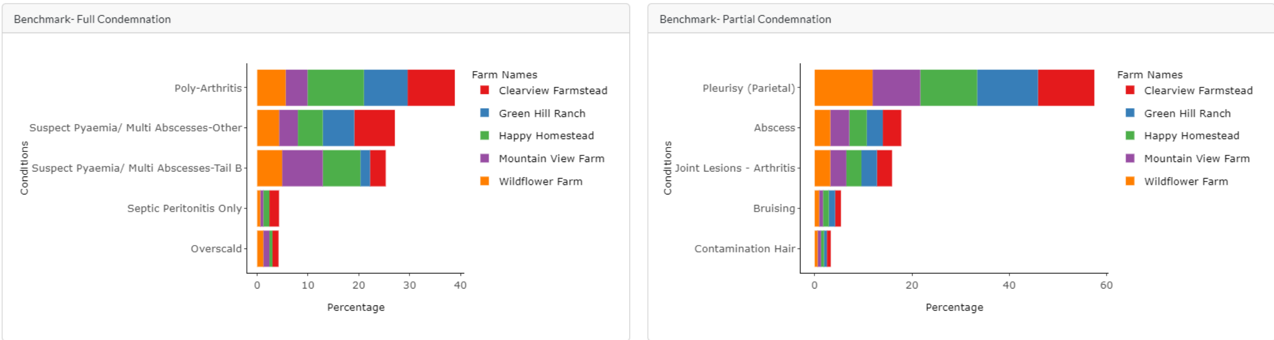


Figure 17. Benchmarking of selected farms.

Figure 18 illustrates the time series for bruising, utilising a basic plot format. This figure incorporates alarms generated through the Holt-Winters method and two CUSUM algorithms, effectively highlighting trends and anomalies over time for enhanced analysis.

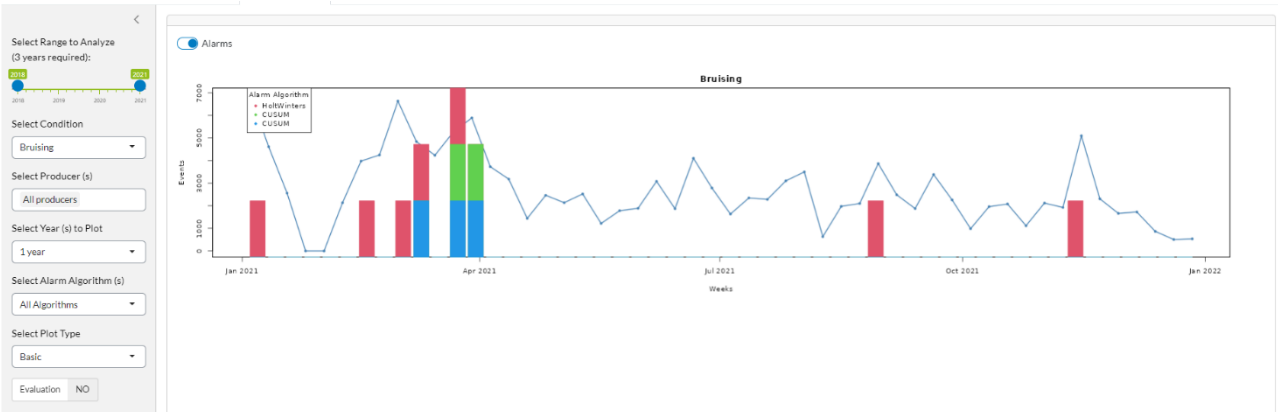


Figure 18. Timeseries for Bruising with alarms (mock dataset).

3.3.7 Involvement of WPs

Metadata of the original dataset used to design this app was shared with WP1. We plan to involve WP5 to improve user interface and user experience (UI/UX) of the app (see 3.3.9). Once this app is describing count data and there is no demographic information on the population sampled, it is not possible to calculate the burden of disease.

3.3.8 Sustainability aspects

The tool is hosted on a server that is managed and maintained by SRUC's IT team

3.3.9 Plan for the remainder of the project

For the remainder of the project, we plan to improve the user interface and experience, to enhance graphical outputs and layouts, develop user profiles, and to refine data upload features, making it more adaptable to other species and countries. To guide these improvements, we will:

- Participate in a joint workshop for testing the usability of the app in collaboration with other countries (Animal Health Ireland – Ireland and Royal GD – The Netherlands). This is to be organised in the first half of 2025 (January to July).
- We will also conduct a tool evaluation with Scottish stakeholders, including industry representatives, and abattoir staff. This is being planned for March-April 2025.
- Adjustments and improvements will be based on stakeholder feedback (March to November 2025).
- Comprehensive tool documentation to ease tool adaptation and reuse for other species and countries (January 2025 to January 2026).
- Study the possibility of adding demographics data to the app – currently, it uses counts data only (January to July 2025).

3.4 Laksetap – Norway

3.4.1 Context

Laksetap, which means "salmon losses" in Norwegian, is a tool for visualizing mortality and other types of losses in captive salmonids at both national and regional levels. The tool was developed to improve benchmarking for end-users by providing historical and recent summaries of mortality in salmonid farms. Additionally, it offers stakeholders standardized methods for calculating mortality, helping them make more informed decisions based on comparable data across farms.

Mortality is an important indicator of fish health and welfare in salmon aquaculture. In countries that are major producers of captive salmon, high mortality rates present a significant challenge. In 2023, over 58 million fish died after being transferred to marine farms in Norway, which amounts to more than 3 out of every 20 fish dying throughout the year. There is considerable regional variation in salmon mortality in Norway.

There is a need for improved systems for benchmarking salmon mortality information for several reasons. One issue is that, unlike other livestock industries where entire groups move into and out of the production phase simultaneously, salmon farming lacks an "all-in, all-out" management practice. Instead, fish are often transferred from freshwater to sea over multiple days or weeks, and this approach also applies during harvest, which can occur at multiple time points. Furthermore, the high number of deaths (often in the thousands or tens of thousands) during the production cycle affects population sizes. These factors complicate mortality tracking, making it challenging to calculate mortality rates consistently for farms from different regions and companies that may adopt varying practices to reduce mortality.

3.4.2 User category/categories

Laksetap has a wide range of users, including salmon farmers, the private sector (veterinarians, fish biologists, vaccine companies, etc.), and the public sector (such as the Norwegian food safety authority, the Norwegian directories of fisheries, the Norwegian Veterinary Institute (NVI), and other research institutions), as well as the general public and consumers interested in understanding salmonid mortality and its impact.

3.4.3 Data source

The data used in Laksetap comes from the Norwegian Directorate of Fisheries (NDF). It includes both open data, such as geolocation and farm license type, as well as confidential industry data. The confidential data includes information on the months during which stocking of fish at sea occurs, fish biomass, and monthly farm-level fish losses in various categories (dead, escaped, discarded, and other). For these confidential data, the app displays only aggregate information as summaries.

3.4.4 Tool architecture

The salmon tools' pipeline is, broadly speaking, the system set up to consume, analyse, and present data at NVI. This is a semi-automated pipeline; parts of it run on a schedule, while other parts involve manual work. The pipeline follows three main dataflows. See the chart below for the steps described (Figure 19). It is worth mentioning that the pipeline developed for Laksetap has elements that could also be applicable for SalmonSyS (section 5.3), although not every dataflow is shared between them.

The first part of the pipeline, involving NDF application programming interface (API), runs on the 21st of each month. It begins with authentication to the API. After successful authentication, an Azure function pulls the data and stores it in a database owned by NVI. An Azure function is a serverless computer service that provides resources on demand. Once the data is stored in the database, it becomes available to researchers. The second part involves downloading XLSX or CSV files from specified data source websites. The goal is to streamline data collection and ensure access to the latest data for analysis. An R script retrieves files from predefined URLs (uniform resource locator – an address on the Web) and stores them in a local directory. The third (not relevant for Laksetap) provides access to data entered directly at NVI database.

The following steps are primarily manual. Researchers log in to the database and explore the data. The final product is a master table containing the required data, which serves as a source for producing summaries by species, time periods (months/weeks/days), and other metrics. These summary tables are then used downstream by other researchers to generate various summaries, including numbers of stocked and dead fish that are crucial for calculating mortality.

Once these tables are available, another R script is run manually to "pin" the data to Posit Connect, our publishing platform (https://posit.co/products/enterprise/connect/). From there, the data becomes accessible to various applications, including the Laksetap Shiny app, as well as other publishing solutions for NVI, such as the Fish Mortality API. The vetinst.no website consumes this API from Connect to display graphs and charts on the NVI's website.

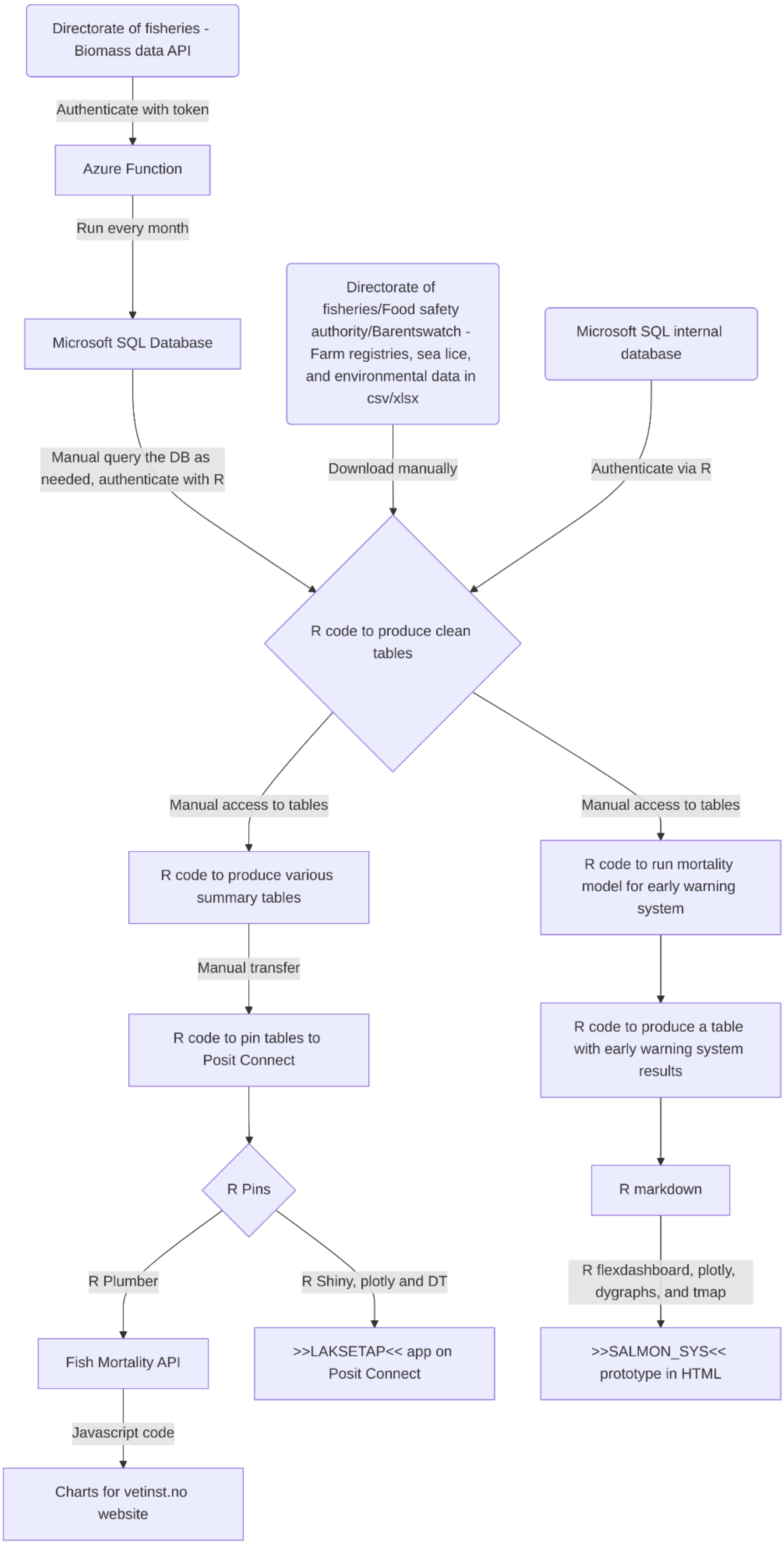


Figure 19. Chart to illustrate the pipeline and dataflow for Laksetap.

3.4.5 User interface (including screenshot)

The Laksetap app is accessible from any browser on a computer or smartphone at http://apps.vetinst.no/Laksetap/. The current version is in Norwegian by default, but browser translation features provide sufficient access to the app in other languages. Figures 3.4.2-8 show screenshots of the Laksetap app. The app includes a sidebar where users can select the species and geographical area of interest, along with eight tabs to display mortality summaries for different periods, mortality calculators, and descriptions of the data sources, as well as explanations of the methods used to handle mortality data and estimate mortality. Further explanations are given under "3.4.6 Content and Functions".

Figure 20. Sidebar of the Laksetap app.

3.4.6 Content and functions

In the sidebar (Figure 20), users can select the species (Atlantic salmon or rainbow trout) and the type of geographical area of interest (production zones, counties or Norway) to display in the main panel.

In the navigation tabs of the main panel, users can choose the period for visualizing fish losses (dead, escaped, discarded, and other) on a monthly or annual basis, either as plots or tables. Users can consult the distribution of fish losses in each category and filter for specific type of losses, month(s), year(s), or area(s) (Figure 21).

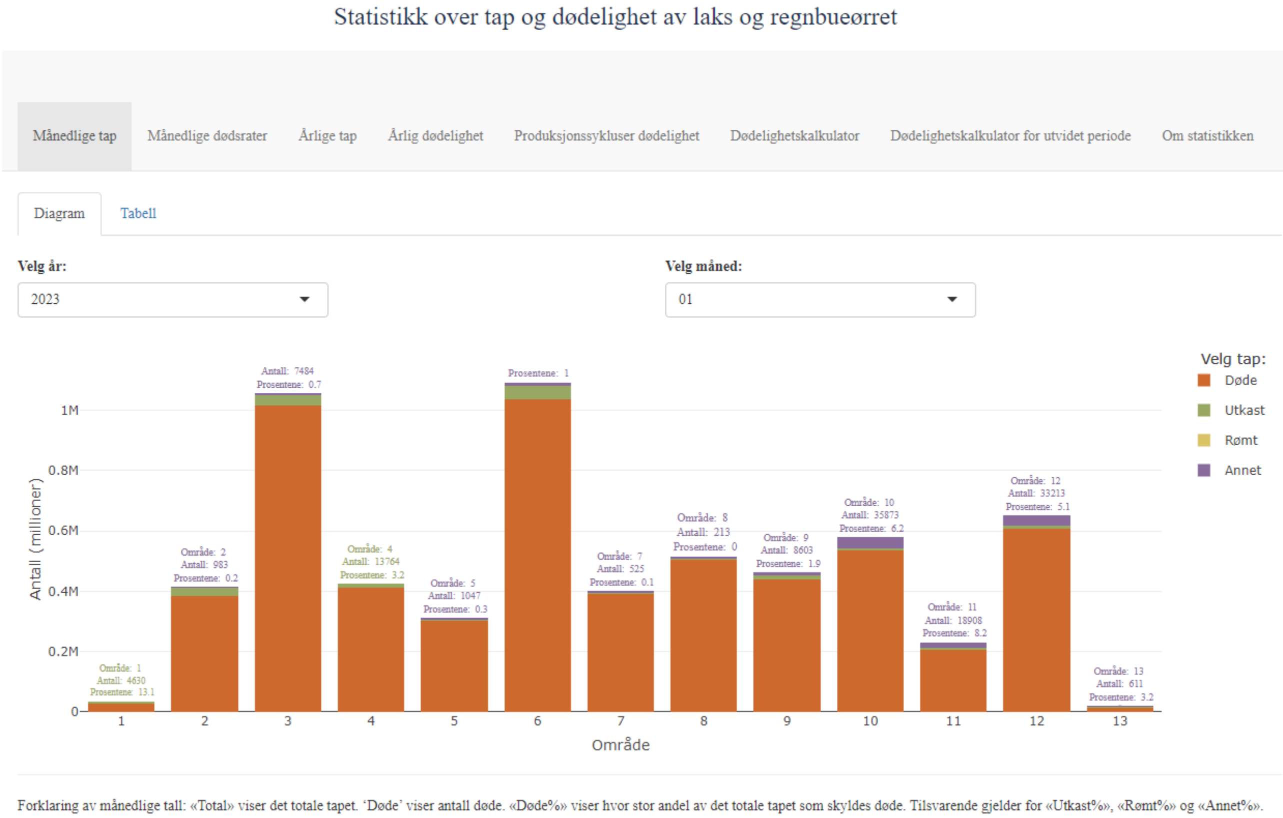


Figure 21. Main panel of Laksetap displaying monthly fish losses in a plot.

For refined mortality estimates, users can consult aggregate level information but calculated from farm-level data. They can access the tabs “Månedelige dødsrater” (i.e., monthly death rates), “Årlig dødelighet” (i.e., annual mortality), and “Produksjonssykluser dødelighet” (i.e., production cycle mortality). These tabs display mortality information through both plots and tables.

The monthly death rates tab shows variations throughout the season, including the median and interquartile range among farms within the selected area (Figure 22). Users can compare death rates between different areas of Norway, as well as between Norway overall and a specific area.

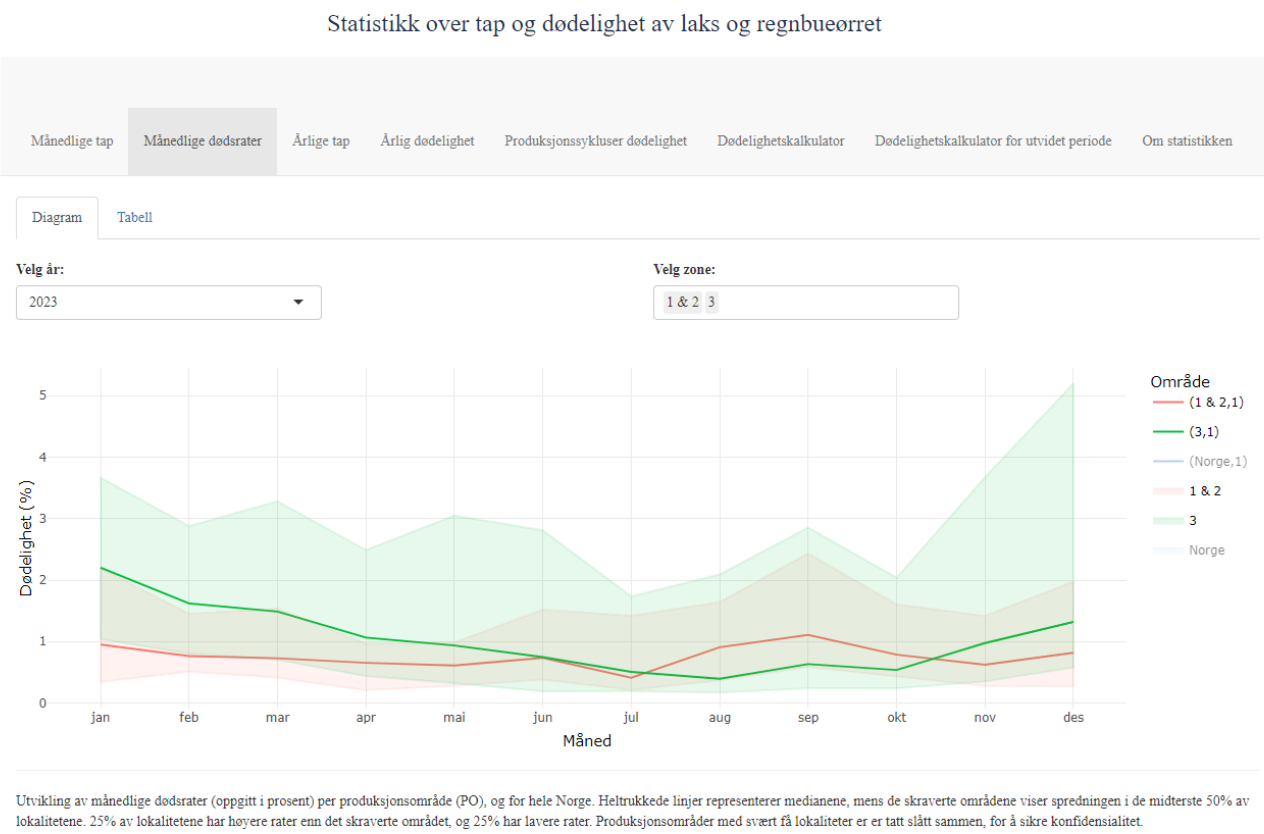


Figure 22. Main panel of Laksetap displaying monthly death rates in a plot.

The annual mortality tab presents cumulative mortality risks for a selected area over each of the past five years (Figure 23), which can be interpreted as the probability, expressed as a percentage, of a fish dying after being transferred to sea within a given year.

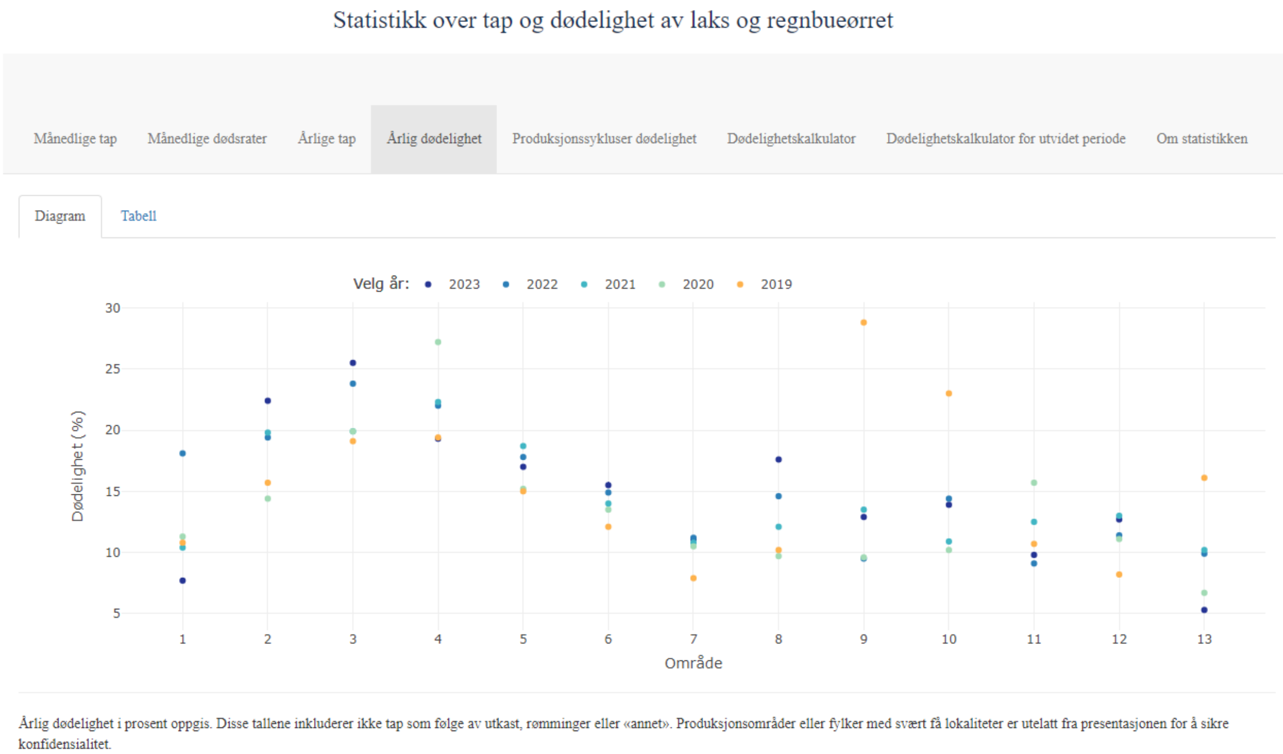


Figure 23. Main panel of Laksetap displaying Annual mortality in a plot.

The production cycle mortality tab also displays cumulative mortality risks, with median and interquartile ranges among farms (Figure 24), but for periods that may exceed one year. This tab reflects mortality over the actual production period at sea for sites that have completed their harvest during the year. Some exclusions apply to the summaries in this tab, restricting mortality estimates to farms producing fish for food consumption, and excluding broodstock farms, research and development facilities, and teaching concessions.

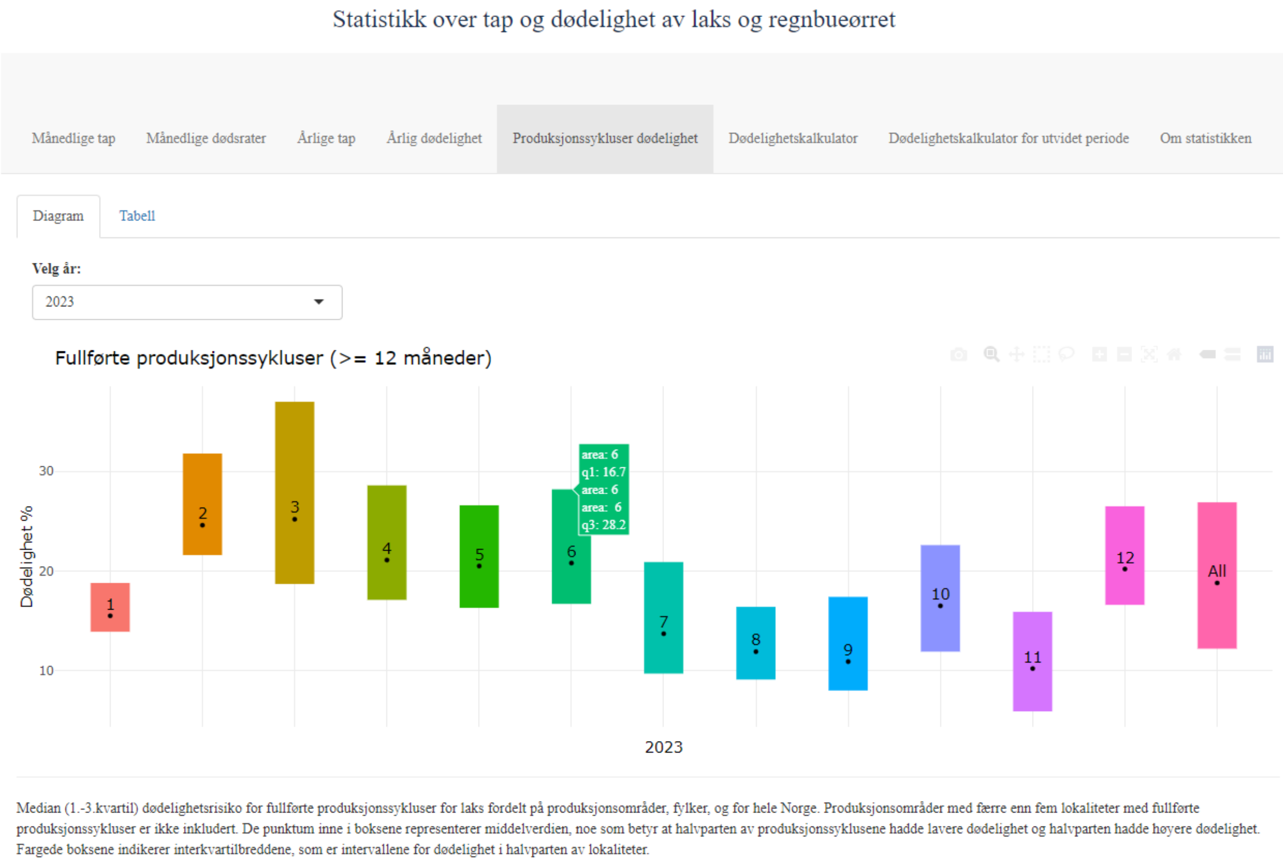


Figure 24. Main panel of Laksetap displaying production cycle mortality in a plot.

Two tabs in the main panel include built-in mortality calculators that allow users to estimate mortality at the farm level.

The "Dødelighetskalkulator" (i.e., mortality calculator) tab estimates mortality for a selected period (e.g., day, week, or month). Users can enter the number of live fish at the start, the number of dead fish during the period, and the number of fish at the end. The calculator provides users with the death rate for the selected period, adjusting for any additions or removals (Figure 25).

Figure 25. Mortality calculator displaying the death rate in a farm.

The "Dødelighetskalkulator for utvidet periode" (i.e., mortality calculator for extended period) tab estimates mortality for past or ongoing production cycles. Users can enter multiple records of mortality from the same production cycle, for consecutive days, weeks, or months. Visualizations based on the user's data are generated to help monitor mortality using death rates and mortality risks (Figure 26).

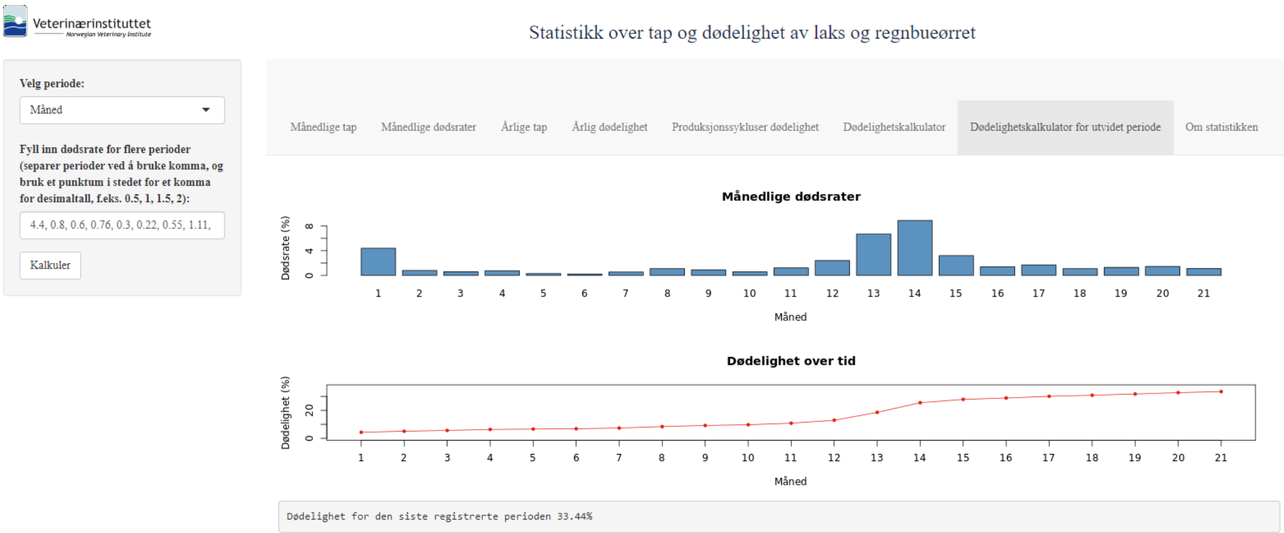


Figure 26. Mortality calculator for extended period displaying monthly death rates and cumulative mortality risk during production in a farm.

3.4.7 Involvement of WPs

There was no involvement of other WPs for the development of this tool so far. We plan to conduct an evaluation of Laksetap using the WP3 framework.

3.4.8 Sustainability aspects

NVI is responsible for reporting salmonid mortality in Norway periodically, making it likely that the Laksetap tool will continue to be used after the DECIDE project concludes. Laksetap is open to end-users, and investigations of its usage rate indicated that a substantial number of people have accessed and interacted with the tool. This engagement has facilitated feedback from users, either during a webinar we organized to showcase the tool or through occasional direct contact with the tool developers.

Among the requests from end-users regarding mortality summaries are more frequent updates, instead of yearly ones, a feature to monitor mortality by weight group, and the ability to download the summaries (plots and tables) directly from the tool.

Additionally, users expressed interest in expanding the functionality of the mortality calculator. Beyond calculating farm-level mortality, the tool could potentially aggregate mortality summaries across groups of farms, such as those under the same ownership or company.

3.4.9 Plan for the remainder of the project

1) Conducting an evaluation using the WP3 framework. April-September 2025.
2) Initiating a new development round that incorporates previously requested features (see the section on Sustainability Aspects) as well as those identified in the evaluation. January-December 2025.
3) Disseminating information to promote the tool's new features. January-March 2026.

4 Prototype descriptions – tools for stakeholder co-creation

4.1 Salmon Mortality Monitor – Scotland, Ireland

4.1.1 Context

At the heart of Ireland and Scotland's thriving aquaculture sector, salmon farming stands as a cornerstone of economic growth and food security. However, the industry grapples with the persistent challenge of salmon mortality, a factor that can significantly impact both profitability and environmental stewardship.

Mortality Monitor is a powerful tool designed to transform raw mortality data into actionable intelligence and including context-of-mortality information, which is currently often lacking in mortality tools.

This innovative platform serves as a vital bridge between data and decision-making, offering farmers, regulators, and researchers an unprecedented view into the complex dynamics of salmon health. By harnessing advanced analytics and intuitive visualizations, Mortality Monitor decodes mortality trends, unveils hidden patterns, and forecasts potential risks. It's not just about numbers; it's about empowering stakeholders to make informed choices that enhance fish welfare, optimize farm management, and drive the industry towards a more sustainable future.

4.1.2 User category/categories

The tool is currently based on synthetic data and primary developed for the Irish salmon industry but has potential to be very useful for Scotland and Norway as well because the context to mortality data is currently often not visualized in these countries.

4.1.3 Data source

Synthetic data was employed for the prototype, with the goal of providing an example of what the visualisation of field data could look like for the Irish salmon industry. This was contingent upon approval from Aquaplan, a stakeholder committee representing the finfish aquaculture industry and state agencies in Ireland. However, at its most recent meeting, this committee decided not to provide data for the tool, considering that the level of data sharing within the industry was adequate.

4.1.4 Tool architecture

The complete flow diagram is shown in Figure 27.

Data Flow

Data Source

The Irish salmon farming industry was intended to serve as the primary data source for this project but is not now going to be provided to DECIDE as a potential product for other salmon producing countries.

Data Ingestion

The data ingestion layer receives a CSV file and performs initial checks to ensure that the data is correctly formatted and meets predefined criteria.

Data Storage

A PostgreSQL database is utilized for storing cleaned and validated data. This robust database system allows for efficient querying, management, and retrieval of data, providing a solid foundation for subsequent analysis and visualization.

Data Processing

Data processing takes place within an RStudio environment. Here, R scripts are executed to perform data cleaning, transformation, and feature engineering. The data is imported from the PostgreSQL database using

SQL queries, allowing for seamless integration between storage and processing stages. Where needed, ontologies could be developed to help synchronization, however, most salmon producing companies use the same software to store data, so data is mostly standardized worldwide.

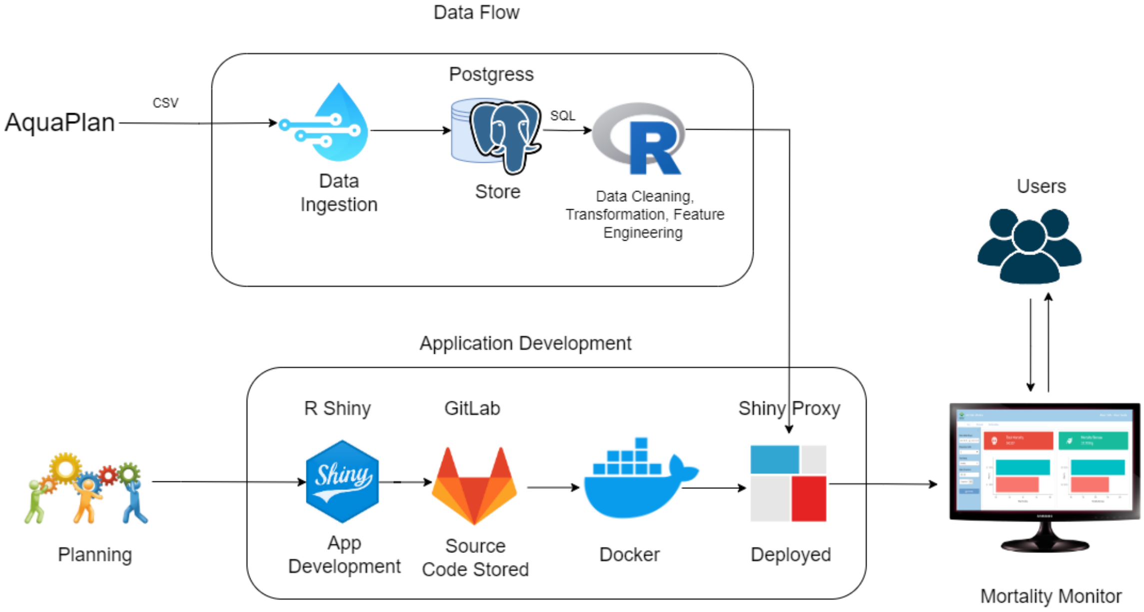


Figure 27. Flow Diagram of Mortality Monitor development stages.

Application Development

Planning

The application planning phase involved a diverse team of experts, including data scientists, epidemiologists, and veterinarians. This multidisciplinary approach ensured that various perspectives were considered, combining technical expertise with domain knowledge. The team engaged with industry stakeholders to gather feedback and insights, which was crucial for identifying specific needs, understanding current challenges in monitoring salmon mortality, and aligning the app's features with industry standards and practices.

App Development

The application was developed using R Shiny based on the gathered requirements. User interface (UI) designs were created with a focus on ease of use, and prototypes were developed to visualize the app's functionality. Feedback was sought from representatives from the Irish industry through Aquaplan to refine the design, seeking to ensure that the final product would meet the needs of its intended users.

Source Code

The source code is managed through GitLab, enabling developers and collaborators to utilize version control with Continuous Integration (CI) activated. This setup facilitates tracking of code changes, supports collaborative development, and automates the testing process to ensure code quality and functionality throughout the development lifecycle.

Docker

A Docker image is created to encapsulate the Shiny application along with all its dependencies. This approach makes it easy to deploy and run the app consistently in different environments, such as on a local machine, a cloud server, or within a container orchestration system like Shiny Proxy, which is used in this case.

Deployment

The application is deployed using Shiny Proxy, an open-source platform. This platform manages user sessions, scales the application as needed, and facilitates access to the Mortality Monitor, ensuring a smooth and efficient user experience.

Users

The end-users can interact with the Mortality Monitor through a web browser, providing a convenient and accessible interface for analysing and visualizing salmon mortality data.

4.1.5 User interface

The dashboard is designed in R shiny.

4.1.6 Content and functions

Our cutting-edge application offers a comprehensive suite of tools for in-depth analysis of salmon mortality data. The application is designed to cater to a wide range of users, from novices to experts, providing valuable insights into salmon mortality and mortality context trends and patterns.

The application features an intuitive interface with three specialized tabs: Basic, Advanced, and Benchmarking. This user-friendly design ensures that users of all skill levels can navigate the application with ease, accessing the information they need efficiently.

Data visualization is a key component of our application. It offers robust profiling of salmon mortality, allowing users to gain a comprehensive understanding of mortality trends and its contexts. The application provides customizable data exploration with advanced filtering capabilities, enabling users to drill down into specific aspects of the data. Users can perform site-level analysis and make site comparisons for selected mortality causes, offering valuable insights into localized trends and potential issues.

Flexibility in data analysis is another strong point of our application. Users can examine data across different periods, including monthly, quarterly, and yearly views. This feature allows for both short-term and long-term trend analysis. Additionally, the application includes benchmarking capabilities, enabling users to compare performance against industry standards or other relevant metrics.

To ensure that the data is presented in an easily digestible format, the application utilizes easy-to-grasp charts. These visual representations of data help users quickly identify patterns, anomalies, and trends that might not be immediately apparent in raw data.

Finally, our application offers the convenience of downloadable PDF reports. This feature allows users to save and share their findings, facilitating communication within teams and with stakeholders. These reports can be invaluable for record-keeping, presentations, and further analysis outside the application.

Figure 28 presents key statistics on mortality for site B. The dashboard is strategically partitioned into two primary sections, each offering distinct insights into mortality data for Site B within the specified timeframe:

- Total Mortality: This section presents an aggregate view of mortality incidents.
- Mortality Biomass: This component quantifies the biological mass associated with mortality events.

Beneath each of these primary sections, bar plots provide a granular, month-by-month visualization of mortality trends. These charts are dynamically filtered to display data exclusively for the selected years and months, enabling precise temporal analysis of mortality patterns at Site B.

Figure 29 shows the comparisons for mortality in site B for November-December against September- October.

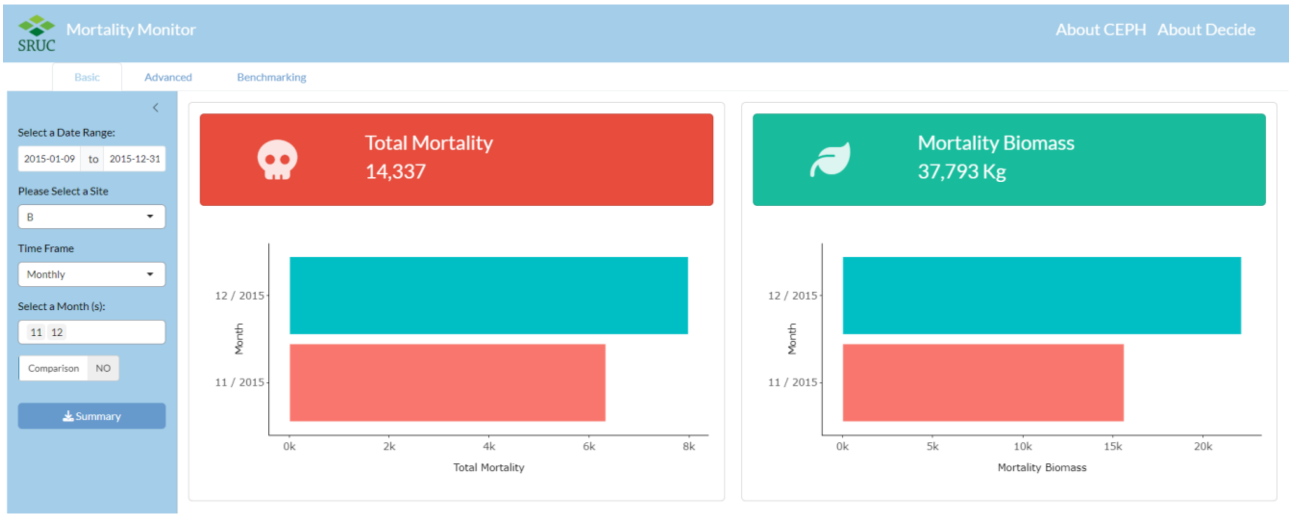


Figure 28. Key mortality statistics for site B.

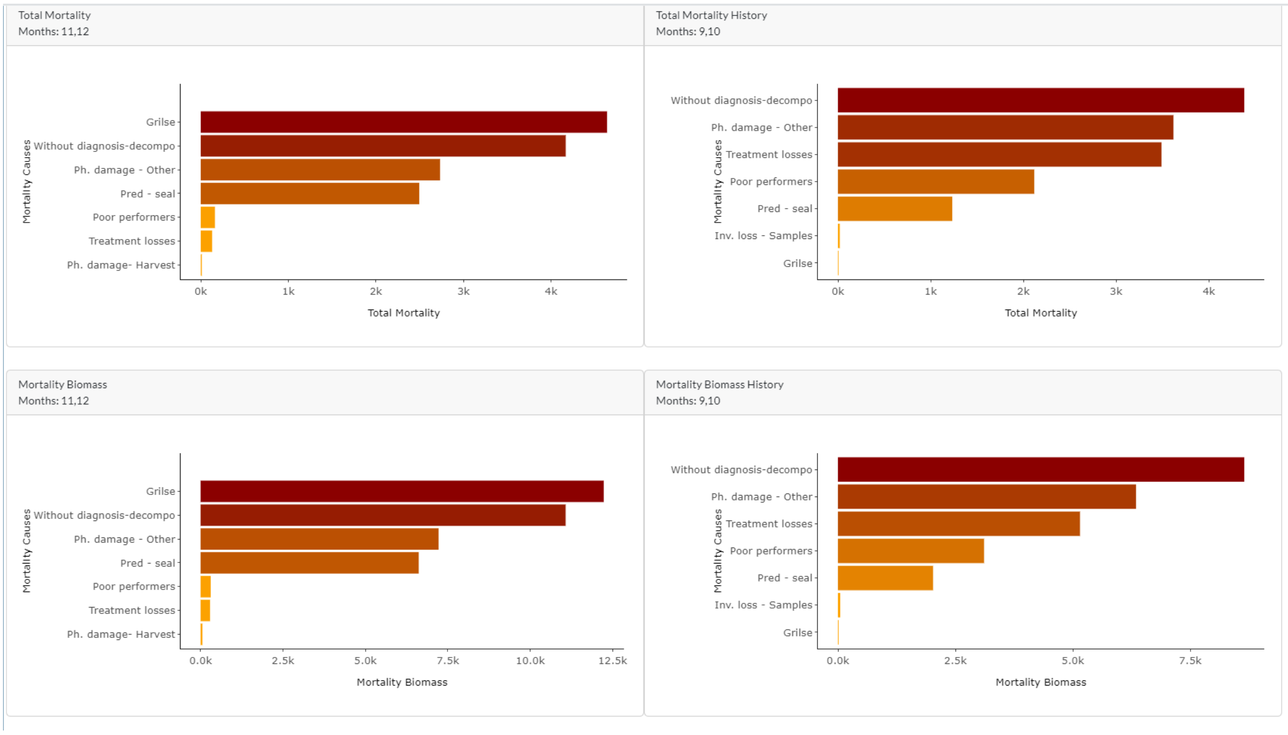


Figure 29. Mortality by Causes for November-December compared with September-October for Site B.

Figure 30 illustrates a comparative analysis of mortality metrics between Site A and Site B. This figure highlights the differences in total mortality rates and mortality biomass for the specified timeframe, providing a visual representation of the trends observed at both sites. The data enables a clear understanding of how mortality patterns vary between these two locations, facilitating further insights into underlying factors that may contribute to these differences.

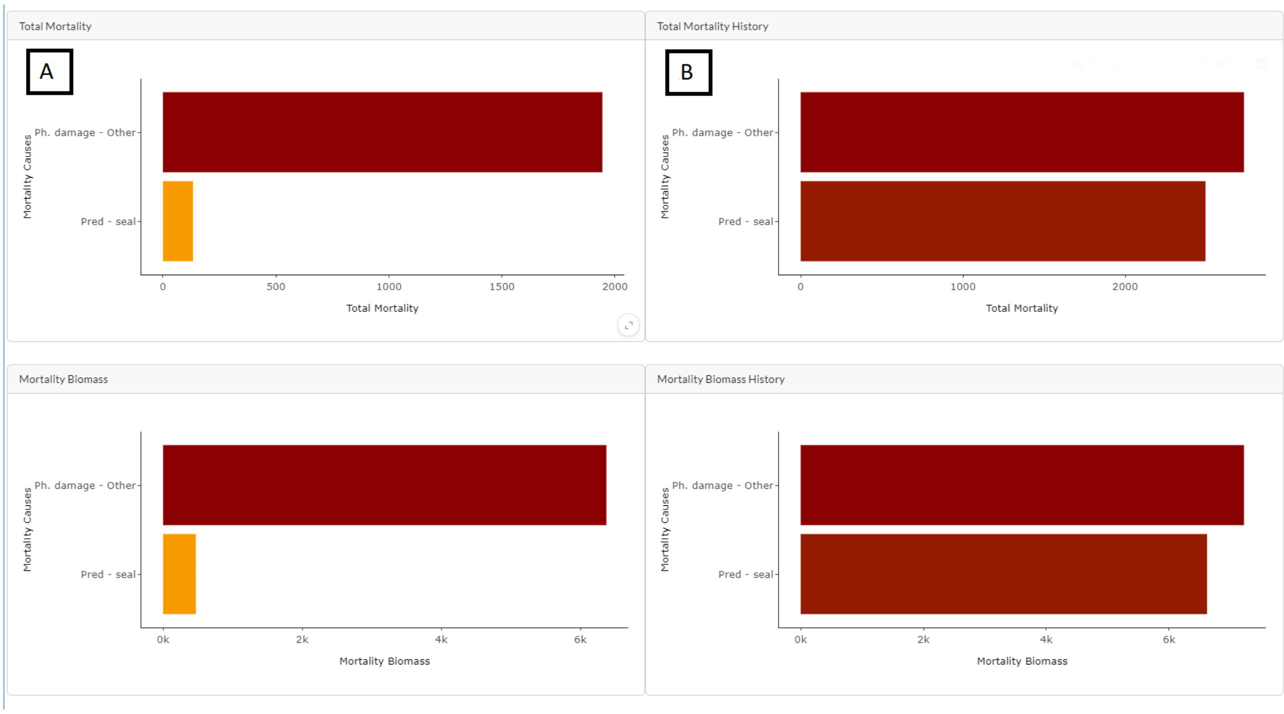


Figure 30. Comparative analysis of Site A and B.

4.1.7 Involvement of WPs

Focus groups were held in conjunction with WP5 to gather feedback and insights, which was crucial for identifying specific needs and concerns, understanding current challenges in monitoring salmon mortality, and aligning the app's features with industry standards and practices. We also plan to involve WP5 to improve user interface and user experience (UI/UX) of the app. The contents of this app have been developed in conjunction with WP2. Mortality metrics were developed to include total mortality rates and also mortality biomass, with the latter a key element of investigating the burden of disease being explored through WP4.

4.1.8 Sustainability aspects

The tool is hosted on a server that is managed and maintained by SRUC's IT team.

4.1.9 Plan for the remainder of the project

- Integrating Time Series for trend analysis (January – June 2025).
- Tool evaluation with Scottish stakeholders (March – November 2025).
- Adjustments based on stakeholder feedback (November 2025 to February 2026).
- Comprehensive tool documentation to ease tool adaptation and reuse for other species and countries (January 2025 to February 2026).

4.2 PigPeaks – Sweden

4.2.1 Context

The majority of pig farms in Sweden manage their records using the production management software PigVision (AgroVision®, https://www.agrovision.com/). The software business model is based on yearly subscriptions (rather than sold licenses). In Sweden, AgroVision is represented by a single vendor, Gård & Djurhälsan (G&D; https://www.gardochdjurhalsan.se/). G&D is a stakeholder in the project. As part of their service to farmers, G&D is responsible for the maintenance of backups for all those farmers who wish to send copies of their data to the secure server maintained by G&D. These farmers can choose to give G&D consent to use their data to publish yearly summaries that help farmers benchmark their own production against national performance indicators (https://www.gardochdjurhalsan.se/winpig/medeltal-och-topplistor/). The PigPeaks prototype aims to use the data backups available at G&D to construct a dashboard of productive performance that will fulfil three main objectives: 1) provide farmers with a more detailed overview of their own data, as well as more regular, more detailed and more interactive benchmarking indicators; 2) engage farmers with a data-driven decision supporting system, starting from indicators they are already used to seeing, and allowing them to start tailoring these indicators to their specific decision needs; 3) support disease prevention and control at the population level for other stakeholders, supported by the guidance and needs of farmers who interact with the dashboard.

PigPeaks was initially considered as two separate tools: PigPeaks Farm and PigPeaks Population. The development of the farm-level prototype as described in deliverable D3.1 is no longer active. Instead, there are plans to incorporate farm-level early warning systems into the currently in-development population-level tool, thereby combining the two tools into one.

4.2.2 User category/categories

Intended users are farmers, their health advisors, and veterinarians. The tool can be used in animal health work on a specific farm, and at the population level. Therefore, experts involved in disease control at the population level (surveillance officials for example) are also potential users.

4.2.3 Data source

Pig production data recorded at the farm by farmers using the software PigVision is sent by farmers, voluntarily, to a central secure server at the company providing them with a PigVision subscription service (G&D in this case). The plan is to include additional data sources in the tool, e.g. meat inspection and antimicrobial use data. These data are already processed at G&D today, which simplifies incorporating them into PigPeaks.

4.2.4 Tool architecture

The tool is developed as an R package, which facilitates sharing as it can easily be downloaded and installed by anyone with access to the R programming language. So far in the development, we have used an internal server to host the tool. Later stages of development will decide on the final hosting solution, considering tool usability, security and implementation feasibility. The optimal solution would be to deploy the tool on G&D's servers and incorporate it into their members' portal, allowing it to use their existing authentication system for user and data access.

4.2.5 User interface

R Shiny is being used to develop the user interface, combined with the plotly and flexdashboard R packages. See Figure 31 below for the current status of the interface.

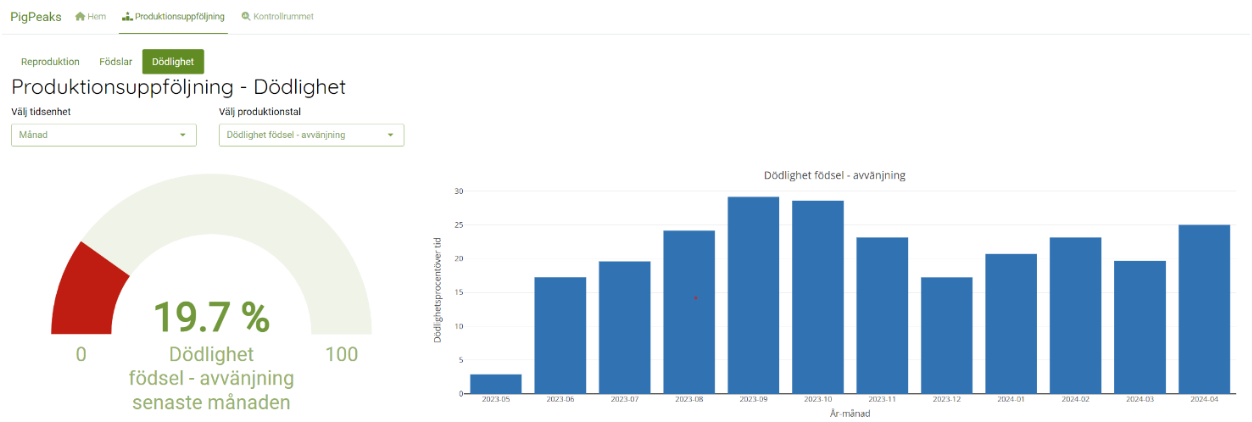


Figure 31. Screenshot of the user interface of PigPeaks.

4.2.6 Content and functions

The current version of the tool shows the development of some selected key indicators over time in a bar chart time series. The collaboration with the stakeholders was initiated before DECIDE started and stemmed from a need to improve PRRS surveillance, i.e. syndromic surveillance also covering reproduction results of sows. For DECIDE, the different indicators of mortality are the ones of main interest. For each indicator, there is also a gauge plot showing the latest result and comparing it to the national average, allowing the user to quickly gauge the current performance in this indicator. See the screenshot above.

4.2.7 Involvement of WPs

WP5 was involved at the start of tool development, when focus groups were held with pig farmers to investigate their use and needs or technologies in their animal health work. We have also had dialogue with WP4 to investigate use of Swedish data for assessment of disease burden. However, Swedish management and husbandry practices were considered too different for the input to match the existing model. We have also had discussions with the stakeholders' organization and disease burden is not part of their prioritized requirements. For WP2, our plan is to investigate if the current model could benefit from the use of the dynamic linear modelling framework developed in DECIDE. It is unclear if there is enough time to expand on this before the end of the project.

4.2.8 Sustainability aspects

Stakeholders on several levels, both farmers and advisors, have expressed the desire to integrate the tool into the current software systems of G&D. If that is the outcome, it is expected that G&D will take on the role of maintaining the tool beyond DECIDE.

4.2.9 Plan for the remainder of the project

- October 2024 – early 2025: continued development, focused on adding an additional data source (either antimicrobial use or meat inspection data) to the prototype.
- 2025 Q1 – Q2: user evaluation, including test user recruitment, preparation and summary of evaluation results.
- 2025 – 2026: further development of the tool based on results from the evaluation and input from stakeholders. Implementation of farm-level early warning system will be attempted by adjusting previous syndromic surveillance algorithms to one selected key indicator. Tool documentation and preparation for GitHub publication.
- January 2026 – June 2026: dissemination of results. Discussion with stakeholders regarding next steps and tool sustainability.

4.3 Pig herd health dashboard – The Netherlands

4.3.1 Context

In the Netherlands there is a lack of adequate tools for swine veterinarians to collect information and to compile data from different sources to properly interpret this information. Therefore, Dutch swine veterinarians are facing a challenge when trying to use available data to take decisions and give advice to their farmers to improve swine health and performance. In order to take decisions to improve animal health in the farms they manage, veterinarians in the Netherlands use data from the Online Monitoring reports (https://www.gddiergezondheid.nl/Diergezondheid/Monitoring/Hoofdpunten-Monitoring-Varkens), from laboratory and necropsy results coming from Royal GD and other diagnostic laboratories, and from the slaughterhouse, among others sources. In addition, they collect information during the farm visits. All these data are displayed in different formats and at different sites (e.g. Royal GD website account, own practice management software, slaughterhouse dashboard from the farmer account…). This poses a challenge to veterinarians, who must invest too much time to put all these data together, if they do it at all. A tool where all these data could be visualized together would help veterinarians to efficiently analyse and use these data for making decisions.

4.3.2 User category/categories

The main users will be swine veterinarians. However, during the project, the possibility of developing different versions for farmers or other swine health advisors will be explored.

4.3.3 Data source

The tool would use input from the Royal GD lab database. Ideally, all laboratory results including PCR, serology, and biochemistry results would be included. However, in a first version, PCR results of respiratory pathogens will be included, as a pilot. Respiratory problems are an important issue in pig production and diagnostics for respiratory pathogens are most often performed. Therefore, a large and continuous flow of PCR results is available. In addition, other lab test results and data from other sources will be explored. This includes a selection of the slaughterhouse data from VION (in first instance also focussing on respiratory-related results) and weather data, antibiotic use, or farm data. However, legal agreements are not in place yet to use the data external to GD.

4.3.4 Tool architecture

Not yet developed. This depends on the data and data sources that will be finally included in the tool.

4.3.5 User interface

User interface still has to be determined. We probably won't be able to deliver a ready-to-access and ready-to-use tool at the end of the project, but we will develop a prototype as much in line as possible with preferences and needs of future users. A first draft is included in Figure 32, which is being evaluated using the WP3 evaluation framework by stakeholders in order to adjust the design to their needs and preferences.

Figure 32. A sketch of the potential layout of the dashboard made with toy data. This is the main and unique screen with a whole overview of different data including lab test results (top-right), antibiotic use, monthly weather data and some moments where interventions are applied (bottom right), main farm visit findings (bottom left) and selected slaughterhouse results (left centre). In the top left there is a time bar, in which a period can be selected to get an historical overview or to zoom in on a specific period.

4.3.6 Content and functions

This will depend on the data sets finally used. As it is now, the prototyped dashboard includes a main and single screen containing an overview of all data included to facilitate the integration and overview of the data

(Figure 32). Lab results are shown in one graph, where different tests can be selected to show all or part of them. In another graph, monthly antibiotic use and monthly outside temperature are displayed. This graph is aligned on the screen with the previous one to related variation in all parameters (i.e. increased percentage of positive PRRS results and antibiotic use was related with a very cold winter, in comparison to other years). In this graph, interventions applied in the farm can be pointed out to compare parameters before and after the intervention. A table where the main health issues noticed by the veterinarians during the monthly farm visits are recorded is also included. This information (based on veterinarians' experience and knowledge) can be checked in relation to data from the other graphs (based on measurements), to see whether what was observed is in line with the findings or other diagnostics, or if intervention is needed. Finally, a selection of slaughterhouse data is included. This data can help to see the impact that certain health issues and/or actions have on the final animal performance. This can support veterinarians in their advice to farmers. All this data can be filtered per time period to show the whole historical view or to zoom in on a certain period of time.

4.3.7 Involvement of WPs

This prototype has been developed based on the input collected from the final users (veterinarians) in different phases using the assistance and support of WP5 and WP3. Including early warning options and a burden of the diseases have been discussed in the focus groups but don't seem to be a key element for the users in the dashboard. Therefore, modelling is not included yet. However, the inclusion of a selection of slaughterhouse data was made based on analysis of correlation between post-mortem data and laboratory test results. This data is not related to an economic value, and there are not perspectives to do so.

4.3.8 Sustainability aspects

The main goal is to design a prototype that really meets future users' needs and preferences. Whether the tool will be developed and/or ready to use or not within the project, is a secondary objective. The plan is therefore to evaluate the prototype made with toy data. Future steps will be to start linking data that Royal GD has access to (lab test results, health issues noted by veterinarians during the farm visits and monthly outside temperature). Finally, legal agreements should be made to link them to other data sources such as antibiotic use or slaughterhouse data.

4.3.9 Plan for the remainder of the project

- One to two evaluation sessions of the tool using toy data will be performed with veterinarians (Q4 2024). This tool will be evaluated by comparing it with another tool included in the DECIDE project with a similar purpose but completely different layout (i.e. a different dashboard for each parameter, different ways of showing data from each parameter). This will provide stakeholders with a wide range of options to choose the combination that fits best their needs.
- Adjustments of the prototype based on the output of the evaluation sessions will be made (Q1-Q2 2025).
- Once there is a clear picture of what the stakeholders would like, we will start further tool development and arranging legal data sharing agreements. First, data that Royal GD has access to (lab test results, health issues noted by veterinarians during the farm visits and monthly outside temperature) and later, other external data (Q3 2025-end of the project).

4.4 Pig HealthCheck System – Ireland

4.4.1 Context

The Pig HealthCheck programme is an Animal Health Ireland (AHI)-led programme co-funded by pig producers and Department of Agriculture Food and Marine (DAFM), with the aim of improving the profitability and sustainability of the Irish pig industry through improved animal health. The programme started in 2019 and currently comprises five key areas:

- Biosecurity: by conducting annual biosecurity assessments on farms.

- Animal welfare: by conducting annual assessments of risk factors for tail biting, based on a tool developed in collaboration with Teagasc, DAFM and AHI.
- Animal health: by capturing, analysing, and reporting of abattoir data from ante- and post-mortem (AM/PM) meat inspection. The AM system is already operational. The PM system is currently being developed by DAFM.
- Antimicrobial usage (AMU): by analysing and displaying AMU, using the database created by DAFM for recording AMU by pig farmers.
- Veterinary public health: by reviewing the National Salmonella Control Programme (NSCP), making recommendations to augment the existing programme by providing direction to increase engagement by both farmers and Private Veterinary Practitioners (PVPs) with the NSCP and to improve the outcomes achieved.

A key element of the programme is the development of an online system where farmers, their veterinarians and other farm advisors can have access to farm data, which are benchmarked with the national data and allow users to monitor their status for a range of measures and to compare this with the national profile. Currently this online system receives data from the five areas mentioned above and these data are displayed in several dashboards with three common functions: displaying the latest results, comparison of those results with the national average, displaying the farm results over time.

4.4.2 User category/categories

Pig farmers, their veterinarians, other farm advisors and AHI. Potential in the future for government (DAFM) and pig processors to have access to some components of the tool.

4.4.3 Data source

The tool uses input from several sources:

- Biosecurity assessment, tail biting risk assessment and salmonella questionnaire: data input from users (veterinarians) into the tool. For biosecurity the BiocheckUGent scoring system is used and the tool has an Application Programming Interface (API) with the BiocheckUGent online system to retrieve the scores for each survey.
- Ante mortem data, Salmonella serology data, antimicrobial usage (AMU) data: data collected by government (DAFM) and transferred to the database provider daily or monthly (frequency varies with frequency of update of the original data).
- Salmonella culture results: data input from the laboratory analysing the samples.

All these data are stored with the database provider - Irish Cattle Breeding federation (ICBF).

The types of data are:

- Scores from 0 to 100 for biosecurity.
- Scores from 0 to 4 per risk category, stocking density, number and type of enrichment items for the risk assessment for tail biting.
- Percentages for several lesions recorded at antemortem inspection in the slaughterhouse.
- Antimicrobial usage per mg/Kg of population in the farm, split by route of administration and type of animals receiving treatment.
- Seroprevalence score for the Salmonella serology data.
- Salmonella bacteriological results.

4.4.4 Tool architecture

Dataflows are shown in Figure 33 and include:

- data from government (DAFM) to ICBF (by upload to webservice or API)
- data input from PVPs through the web system (webservice) to ICBF

- data upload from laboratories through the webservice to ICBF
- data flow between ICBF and BiocheckUGent through API (ICBF provides pseudonymized data to BiocheckUGent and receives scores from BiocheckUGent)

Data model integrates historical data (data collected before the database and web system were set up) and new data (after the web system was set up).

Antemortem (AM) data are updated daily (end of the day), AMU and Salmonella serology data are updated monthly, while biosecurity and tail biting data are updated annually. Salmonella culture results are uploaded weekly by the laboratories.

AM data:

Data requested via REST webservice daily, following an OAuth industry-standard protocol for authorization (https://oauth.net/2/). Credentials are checked to confirm authorisation of upload of data.

AMU and Salmonella serology results:

Data file imports (file in csv format)

Biosecurity and Tail biting risk assessments:

Relational database tables marry new data and historical data

Assessments are captured as JSON, using JS library and OS, browser & device flexibility (format adapts to type of device being used, e.g. laptop, mobile)

REST webservice to/from UGent for getting the biosecurity scores

Reports (to be used for quality assurance scheme purposes) are generated via HTML to PDF

Salmonella Questionnaire:

Assessments are captured as JSON, using JS library and OS, browser & device flexibility (format adapts to type of device being used, e.g. laptop, mobile)

Salmonella culture results:

Data file imports (file in csv format) via webservice.

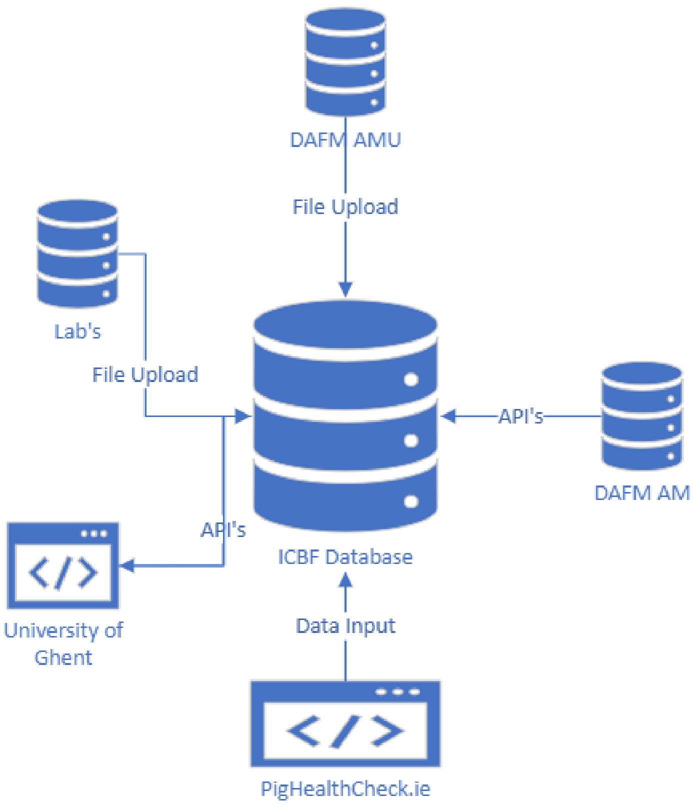


Figure 33. Pig HealthCheck System database and its different dataflow.

4.4.5 User interface (including screenshot)

The tool was developed using an Oracle database and mixture of different front-end technologies for the application, including PHP, JavaScript, CSS and HTML.
Users access the tool via an online system: https://pigs.icbf.com/sign-in (Figure 34).

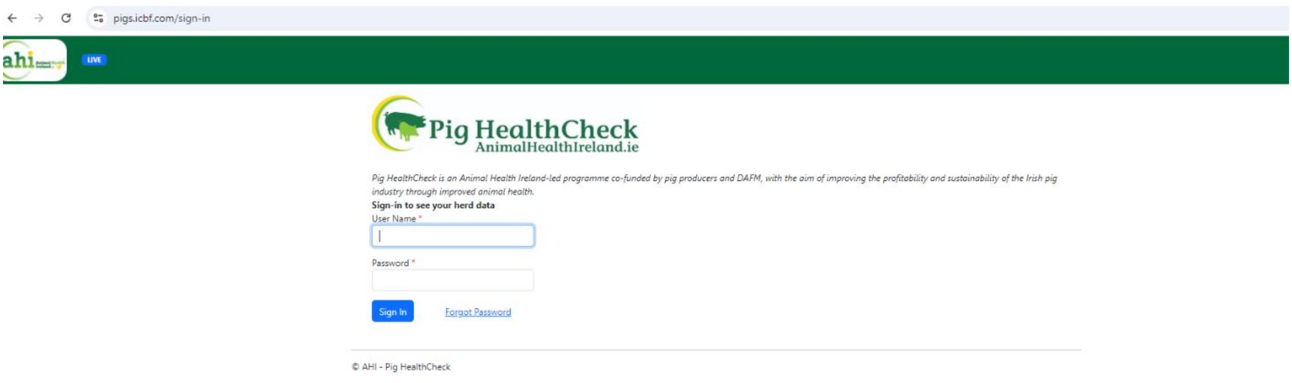


Figure 34. Screenshot of the access page to the dashboards.

They have a username (e.g., herd number) and a password set up by the user. For this a master list provided by DAFM was used with the email address for each farm. For veterinarians and other advisors, AHI curated the list with their email addresses so they can set up their password.

4.4.6 Content and functions

The epidemiological unit is the farm, and results are aggregated at farm level.

There are three input surveys in the tool: biosecurity assessment, tail biting risk assessment, and Salmonella questionnaire, where the veterinarians input the data directly into the tool (Figure 35).

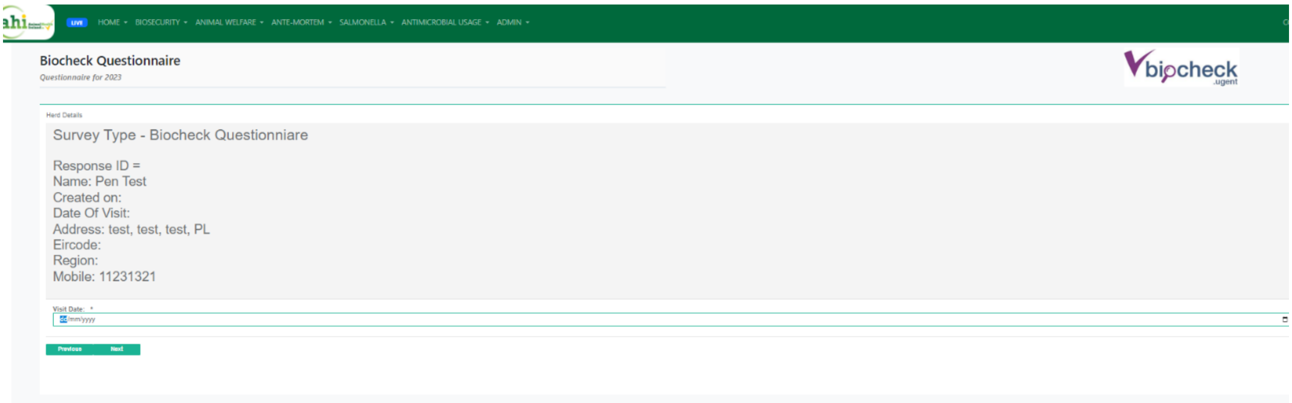
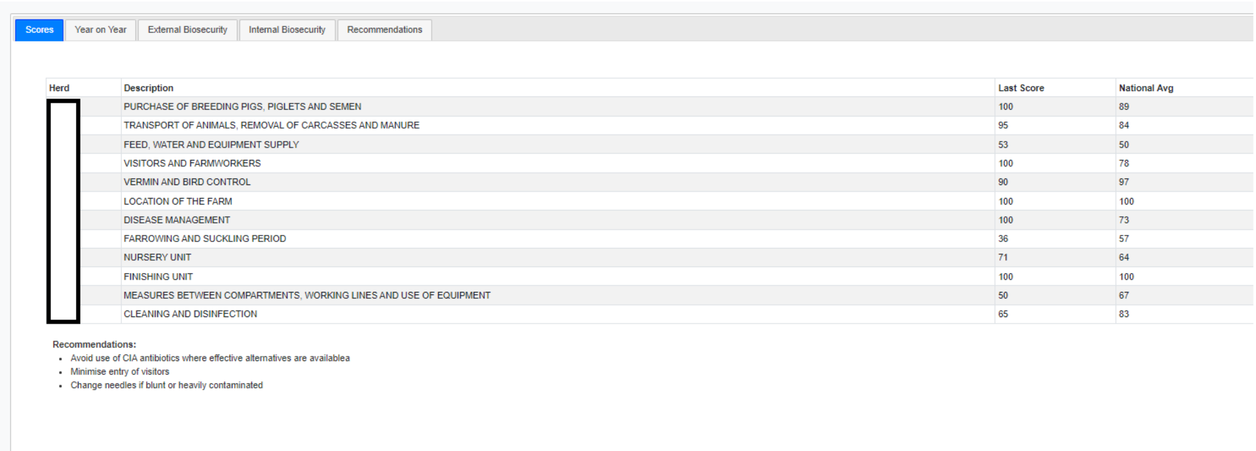


Figure 35. Screenshot of the first page of the biosecurity survey.

The three main functions in all five dashboards are:

1) Displaying the latest results (Figure 36)
2) Benchmarking the results with national results (Figure 37)
3) Displaying results for the farm over time (Figure 38)



Scores | Year on Year | External Biosecurity | Internal Biosecurity | Recommendations

Herd	Description	Last Score	National Avg
	PURCHASE OF BREEDING PIGS, PIGLETS AND SEMEN	100	89
	TRANSPORT OF ANIMALS, REMOVAL OF CARCASSES AND MANURE	95	84
	FEED, WATER AND EQUIPMENT SUPPLY	53	50
	VISITORS AND FARMWORKERS	100	78
	VERMIN AND BIRD CONTROL	90	97
	LOCATION OF THE FARM	100	100
	DISEASE MANAGEMENT	100	73
	FARROWING AND SUCKLING PERIOD	36	57
	NURSERY UNIT	71	64
	FINISHING UNIT	100	100
	MEASURES BETWEEN COMPARTMENTS, WORKING LINES AND USE OF EQUIPMENT	50	67
	CLEANING AND DISINFECTION	65	83

Recommendations:
- Avoid use of CIA antibiotics where effective alternatives are availablea
- Minimise entry of visitors
- Change needles if blunt or heavily contaminated

Figure 36. Screenshot of the biosecurity dashboard showing the latest result for a farm.

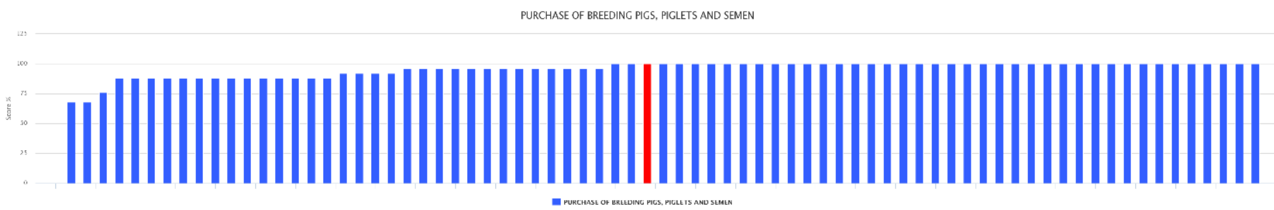


Figure 37. Screenshot of the biosecurity dashboard benchmarking the farm result for Purchase of breeding pigs, piglets, and semen with the other farm results. Red bar shows farm results, while the blue bars are other farms' results.

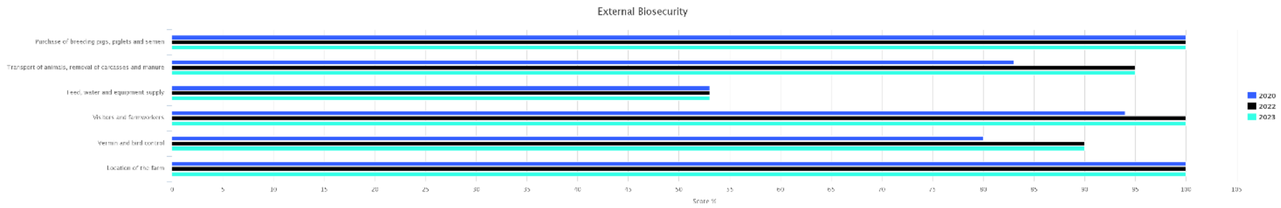


Figure 38. Screenshot of the biosecurity dashboard showing the results for external biosecurity for a given farm over time.

Users can use the dashboards to identify problems at farm level (high AMU, aspects of biosecurity that require improvement, welfare risks, lesions with high prevalence, etc.) and to follow management changes at farm level (e.g., to verify if the introduction of a vaccine has reduced AMU).

4.4.7 Involvement of WPs

WP3 and 5 have been involved in the assessment of the tool users' needs and development of the evaluation of the tool by the users. During 2025 we will discuss with WP4 if the global burden of disease methodology can be included into the tool. No disease modelling is expected to be included in the tool.

4.4.8 Sustainability aspects

This tool is part of the AHI Pig HealthCheck programme, with funding secured for the next 5 years. Currently, this online tool has been accessed by the farmers of 190 pig units (there are around 350 commercial pig farms in Ireland). To improve the tool, it is important to understand how the tool is being used by farmers and their advisors (veterinarians and other farm advisors) in terms of their usability and usefulness. The lessons learned can then be applied to other countries and dashboards in terms of the functions they should contain. An evaluation survey was conducted during early 2024 and workshops will be conducted during November and December 2024 to co-develop with users the next phase of the dashboards based on the feedback from the evaluation survey.

4.4.9 Plan for the remainder of the project

- November 2024 to May 2025: workshops to co-develop the postmortem (PM) component of the dashboards and re-design of the current dashboards based on the feedback received so far from users
- February 2025 to June 2025: PM dashboard development and re-design of the dashboards based on the feedback of the workshops
- December 2025 to January 2026: second round of evaluation of the dashboards
- March 2026 to June 2026: adjustment of the dashboards based on the second-round evaluation feedback

4.5 Purchase Assistant – Norway, Sweden

4.5.1 Context

The Purchase Assistant is a version of the Purchase Risk Meter tool described above. Development of the tool began in Sweden. Currently, it is being tailored for use in Norway as well. Later in the project, leveraging the insights gained from adapting the tool to the Norwegian context, we plan to explore its adaptation for other countries such as the Netherlands and Belgium.

The Swedish version of the Purchase Assistant is called FriskKo app, and it is being developed to fit the needs of the main Swedish cattle association (Växa) in the context of their voluntary safe trade program (FriskKo). In this program, bulk tank milk samples from participant farmers are taken quarterly, and analysed at SVA for *Salmonella spp.*, *Mycoplasma bovis*, *Streptococcus agalactiae*, Bovine respiratory syncytial virus (BRSV), and Bovine coronavirus. The safe trade program incorporates participating herds into the Green List according to their last four laboratory results, i.e., those herds that have tested negative for all pathogens in the last four samples are included in the Green List, whereas those that have had at least one test positive to at least one of the pathogens in the last four samples are not.

The Norwegian version of the Purchase Assistant is being developed to fit the needs of the main dairy farm cooperative in Norway (TINE) and MIMIRO, a technology company established by TINE and Felleskjøpet Agri.

Regular meetings are being held in Sweden between SVA and Växa advisors to develop the tool in an iterative manner. Meeting between NVI and TINE/MIMIRO are being held in Norway. Topics discussed include user requirements, workflow, data pipelines, pathogens of interest and hosting solutions for the final tool. Initially, Växa advisors requested an interactive tool that could be adapted to include more input data other than bulk tank milk test results (i.e., herd size, trading networks, production system, etc.) and outputs beyond test results (i.e., matching list of farmers with similar health status), with different levels of access depending on the user. After a first version of the tool was presented to a limited group of farmers, discussions are focused on how to make it helpful and what can be achievable in the remaining time in the project.

4.5.2 User category/categories

The anticipated users are participant farmers of the FriskKo program, animal brokers, and farm advisors at Växa. In our initial evaluation of the tool with users, veterinarians have shown interest in the tool. However, dairy farmers have shown little interest in the tool and are sceptical of the need for the tool with the functionalities of the FriskKo app.

In Norway the app has been demonstrated to MIMIRO and TINE, who show interest in the app. It has not been presented to farmers or animal brokers.

4.5.3 Data source

Växa is the Swedish data owner of the laboratory results for each of the participating farms. For tool development during the proof-of-concept phase, Växa shared with SVA a .csv file containing a series of laboratory results from bulk tank milk samples. The toy dataset is being used to develop codes to clean and organize the data using the R software for statistical computing. The structure of the dataset is being used to create a dataset with fake results that better fit the purpose of the tool evaluation.

For Norway, data from laboratory results from bulk tank milk samples will be used. These data are owned and managed by TINE. A potential problem with the Norwegian data is that they are not part of a regular surveillance program. Also, the pathogens chosen as examples in Sweden, *Salmonella spp.*, *Mycoplasma bovis* are not relevant in Norway, as they are both notifiable diseases in Norway. For Norway, the primary candidate as pathogen of interest is *Streptococcus agalactiae*, for which TINE provides data.

In Norway it has been proposed to use the Purchase assistant app to show risks for respiratory infections, such as bovine coronavirus and bovine respiratory disease. Information about the risk of infection for these diseases will be based on early warning models using data from the “Kukontrollen” as model inputs, administrated by TINE and owned by MIMIRO, of which 97% of dairy herds are members. Kukontrollen records and processes data from dairy herds, including data from health portals, slaughterhouses, and dairies.

4.5.4 Tool architecture

Long-term solutions for the data pipelines are yet to be identified, and different software solutions and IT infrastructure will be identified depending on user’s technical requirements.

4.5.5 User interface

During the development of the proof-of-concept, R Shiny is being used. Access to the Swedish tool will depend on the long-term hosting solution that is identified, although some level of user authentication is foreseen at this time.

For Norway, user authentication is considered a necessary part of the tool. A possible solution is that the tool is added as a part of "Kukontrollen", where user authentication is already incorporated. It is also foreseen that some additional features are needed for parameters of which users might agree or disagree to share information with other users.

4.5.6 Content and functions

In the first version of the Swedish tool (summer 2023 – fall 2024), users can enter the number of animals to be purchased and herd ID from which they wish to purchase the animals (seller farm). If the seller herd is on the list of FriskKo program participant herds, information on whether the seller herd is included in the Green List will be shown in the overview tab. Detailed results for individual pathogens can be seen in separate tabs (one tab per pathogen). Seller herds that either do not participate in the FriskKo program or do participate but are not included in the Green List due to positive tests to at least one of the pathogens, will be shown as "unknown status".

The next version of the Swedish tool (summer 2025) will be discussed once the first evaluation is finished (fall 2024). Based on the results of the tool evaluation, the interface will be modified if needed according to participant feedback. Also, additional functionalities may be explored, which may include the purchasing herd ID as user input and based on the last four tests, the output will be a list of herd IDs with the same health status.

For Norway, it is of particular interest if additional functionalities, like risks on a more continuous scale than just binary (red vs. green) might be added as a feature.

4.5.7 Involvement of WPs

WP3 has been involved in the development of the evaluation of the tool by the users. The functionality of the tool was developed based on user's requirements and priorities. At the current development stage, models developed by WP2 and WP4 have not been within the user's priorities. However, the user may consider incorporating those in the future. The development of such functions within the timeline of the DECIDE project remains unclear.

4.5.8 Sustainability aspects

Both Swedish and Norwegian stakeholders have expressed a desire to integrate the tool into their current software. It is expected that the stakeholders will have a business plan for the use of the tool beyond the DECIDE project.

4.5.9 Plan for the remainder of the project

Swedish timeline:

- October 2024: finish first evaluation round in Sweden.
- October 2024 - December 2024: define objectives for the next development round.
- January 2025 - June 2025: make adjustments to the tool based on evaluation.
- July 2025 – December 2025: finish tool documentation, work on all the necessary information to make the tool available in the GitHub repository.
- January 2026 – June 2026: dissemination of results to users through Växa's communication channels, dissemination of results to scientific communities. Update training materials.

Norwegian timeline:

- January 2025 - June 2025: make adjustments to the tool, translate to Norwegian.
- July 2025 – December 2025: finish tool documentation, work on all the necessary information to make the tool available in the GitHub repository.
- January 2026 – June 2026: dissemination of results to users through TINE/ MIMIRO communication channels.

5 Prototype descriptions – tools for data analysis innovation

5.1 Broiler Virus circulation – Poland

5.1.1 Context

Poland is the biggest producer of broiler chickens in Europe, with 80% of its production coming from highly integrated production systems. Several endemic viral diseases (e.g., gumboro virus, avian infectious bronchitis, and avian Metapneumovirus) circulate in the population, but limited information is available on these despite the need for producers to make costly decisions to prevent infections. Indeed, depending on the context, different vaccination protocols could be effective. WP4 is currently studying the impact of the circulation of these viruses on Polish broiler producers.

Currently, veterinarians, farmers and integrators diagnose these diseases through clinical signs or laboratory tests. However, due to vaccination, the laboratory test results are not binary (yes or no). Determining the circulation of field strains of these viruses is very cumbersome for veterinarians and requires several sources of information to be integrated and analysed together. The proposed tool has been developed to support the better identification of virus circulation and implement a targeted vaccination strategy based on data. The goal is not only to ease the interpretation of the diagnostic results but also to provide the user with information about epidemic surveillance and the most up-to-date information on the circulation of certain virus strains.

5.1.2 User category/categories

This tool will be used mainly by veterinary diagnostic laboratories and their clients from the broiler industry (broiler producers, technicians, integrators, veterinarians).

5.1.3 Data source

The two data sources used as input for the tool are the veterinary diagnostic laboratory and its clients. The tool will provide an interface allowing data collection, restricted by an individual code defined by the laboratory, to ensure data quality and correctness. The identification data will be kept to a minimum (e.g., unique analysis ID and commune of the flock) to respect legislation on personal data and good data protection practices.

5.1.4 Tool architecture

The prototype will be constructed based on historical data already provided by the stakeholders. However, it is planned that the tool can collect additional data. All data will be saved in a relational database (PostgreSQL). For the prototype, this database will be hosted locally for development. Geographical data will be acquired from open data sources. RShiny will be used to develop the user interface and communicate with the database. The tool will be designed with version control.

5.1.5 User interface

The user interface (UI) is in development, and no screenshots are available yet. The planned structure of the UI is, however, described below. The UI will be based on two tabs:

Diagnosis tab: This tab will allow users to get information about virus circulation in their flock. The users will be able to enter all the information they have about the flock's viral status, such as PCR and serology results, vaccination status and geographical location, into the tool. The tool will estimate viral circulation in the flock based on the input information. This will be later combined with additional information about the flock's infection burden based on the work conducted with WP4.

Overview of virus circulation: This tab provides general information about virus circulation based on data entered by all the users. The data will be displayed on a geographical scale that avoids the identification of individual farms. The user can provide a commune to filter and modify the outputs, so the tool can provide targeted information about virus circulation around his/her farm. The interface will carefully underline that the data collected and information displayed are based on voluntary data reports; therefore, true incidence/prevalence cannot be extrapolated from this data. This information will be designed to support users in the choice of their vaccination protocol.

5.1.6 Content and Functions

Overall, the tool's goals are to 1) support the interpretation of the laboratory diagnosis of virus circulation in Polish broilers and 2) support the identification of the best vaccination strategy based on the available viral circulation information. Additionally, the tool will contain information about the cost and burden of these viruses on broiler flocks in Poland.

5.1.7 Involvement of WPs

The data integration required the support of WP1 with whom the tool developer collaborated. Furthermore, a stakeholder consultation is occurring with the support of WP5 to better define the users' need and capabilities in decision support tools. Defining the tool's purpose and source data was the result of these two questions: what data sources are available, and what are the user's needs. Once a first prototype has been developed, an evaluation in collaboration with WP3 and WP5 is expected to occur. Furthermore, the tool developers are working together with WP4, on exploring the disease burden of Polish broiler production. The analysis is mainly focused on viral diseases such as infectious bronchitis for which disease burden information is scarce. If fruitful, the results of this collaboration are expected to be integrated into the tool.

5.1.8 Sustainability aspects

The tool is a prototype. It will be tested with clients from our partner laboratory. If the prototype meets the promise, discussions are ongoing to deploy the tool in their systems. Further potential development in providing additional services has also been considered and will be developed if the stakeholders have enough interest and funding.

5.1.9 Plan for the remainder of the project

The current work plan is the following:

- Create a prototype by spring 2025
- Analysis of the virus cost or burden in collaboration with WP4 to be integrated into the tool by summer 2025
- Pilot the prototype in autumn 2025 with an evaluation if possible.

5.2 Broiler Monitoring Dashboard – Italy, the Netherlands

5.2.1 Context

In the Netherlands, poultry farmers are independent farmers and record their own data. Important sources of data are daily farm data, which can be different for each farmer, reports from the slaughterhouse, and national programmes (obligatory or voluntary). The Netherlands has multiple national monitoring programmes. These include registration of all antibiotic prescriptions, registration of transport of broiler flocks, scoring of footpad lesions at slaughter, and determining the vaccination status against Newcastle disease (of which the Netherlands is free) by hemagglutination inhibition (HI) assay. The purpose of our tool is to create a more complete view of broiler production in the Netherlands. The dashboard can show farm-specific data and national aggregated data, which can be used for benchmarking. This general dashboard can also be modified to show different data, such as performance results, which are currently not available from Dutch farms, but could be available in other datasets such as integrator data (Italy).

5.2.2 User category/categories

The tool is designed for poultry farmers and veterinarians

5.2.3 Data source

Netherlands

We use data from the Poultry Monitoring Program combined with the Central Registration of Antibiotics, which is data owned by AVINED (the Dutch poultry association) and managed by Royal GD. We received slaughter data from AVINED directly. From Royal GD, we received diagnostic laboratory data.

Italy

We received data from the Italian integration Veronesi. These data include performance data, footpad lesion scores, and antibiotic treatments.

5.2.4 Tool architecture

Currently, the data pipeline for the Dutch data is as follows (see Figure 39):

- Datasets from AVINED and Royal GD are sent to UU by secure data transfer. The data is stored at UU's Microsoft Azure Storage. Ontologies are created and available.
- The datasets are cleaned, filtered, and merged in Databricks using PySpark.
- The combined dataset is stored as a csv file at a local computer.
- The dataset is loaded into Tableau on the local computer and used to create the dashboard.

Currently, data from all farms is loaded into the tool and aggregated results (such as median FPL scores) are calculated within Tableau. For future use, only the aggregated data could be in the tool, preferably together with data from one farm, the farm of the tool user. Methods to achieve this will likely not be developed within the project.

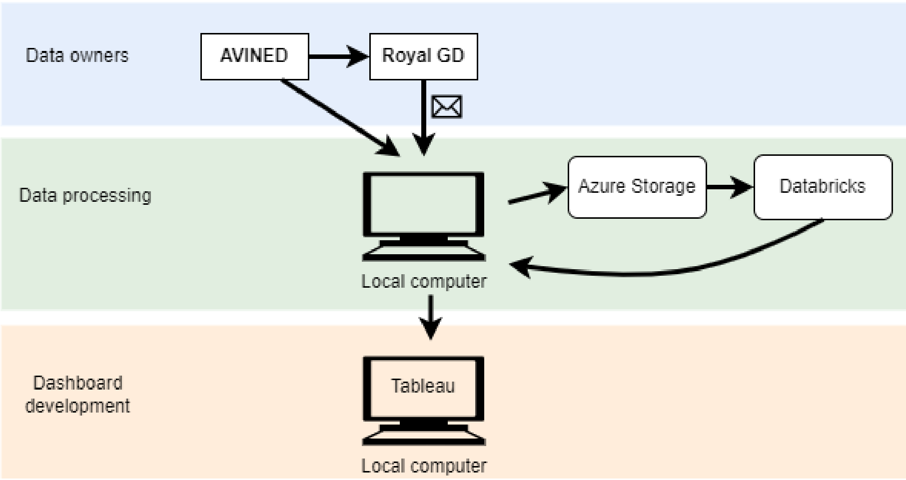


Figure 39. Data pipeline for Dutch data in the Broiler Monitoring Dashboard.

5.2.5 User interface

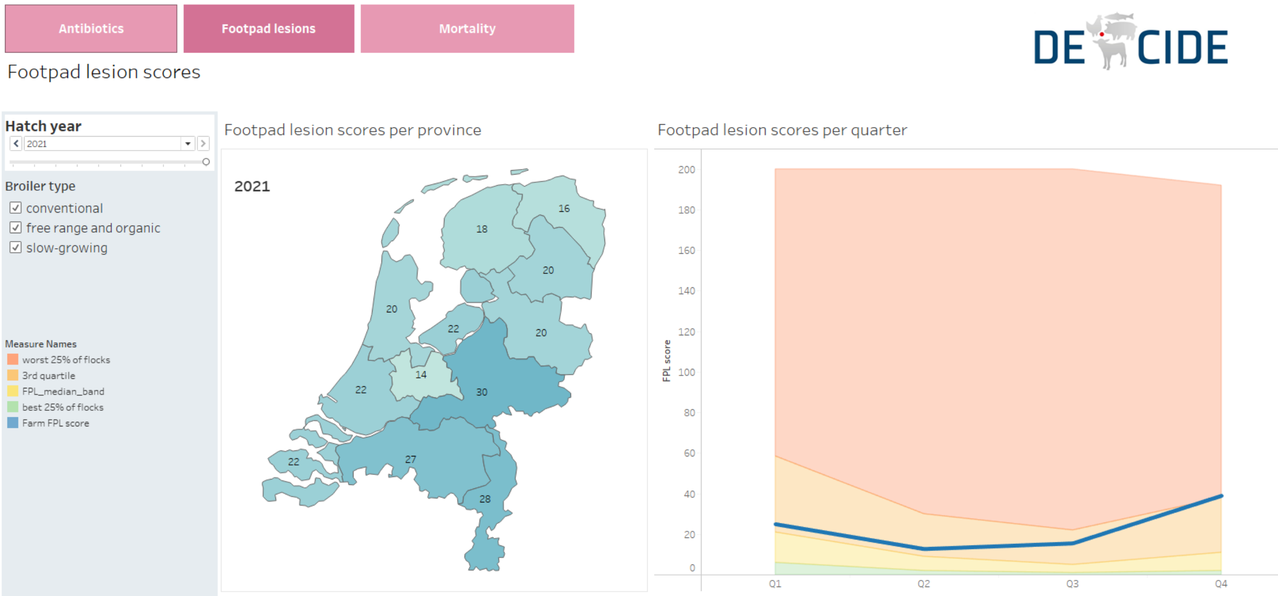


Figure 40. Current user interface of the Broiler Monitoring Dashboard.

Figure 40 shows the current user interface. Only antibiotic use, footpad lesions and mortality are visible, but this can be expanded to other metrics. The right graph shows farm-specific data (blue line) and benchmark values. Data can be filtered on broiler type to compare a farm with either other farms with the same broiler type or with all farms.

5.2.6 Content and functions

The main goal of the dashboard is benchmarking. A prediction model for footpad lesion scores has been developed using several methods such as dynamic linear modelling (in collaboration with UCPH) and random forests. The aim of those models is to warn the farmer if the footpad lesion scores at slaughter will be too high. However, currently the predictive performance of this model is not high enough for inclusion in a decision support tool, because many false-positive and false-negative predictions would decrease the trustworthiness of the tool.

5.2.7 Involvement of WPs

Together with WP1, an ontology for this tool, at least specifically for the Dutch data, is in development. The data that is visualized in this tool is also used as a use case for federated analysis, although this will not be integrated in the (user interface of) the tool. The work on prediction models for footpad lesions (see 5.2.6) has been conducted in close collaboration with WP2. Lastly, work has been done within WP4 to assess the impact of first-week mortality on broiler performance using Italian data, which can be included in the tool.

5.2.8 Sustainability aspects

There are currently no concrete plans for sustaining the tool after the project. The complexity of the data pipeline and challenges with data which are both private and sensitive make this tool less suitable to be incorporated in existing tools from either Avined or Royal GD. The Italian integrator could be an alternative user who could host this tool for internal use. However, data are currently not collected in one electronic file; instead, different files are manually linked. Finishing a tool that will be sustainable after DECIDE is not likely given the amount of time and work it would require from the integrator.

5.2.9 Plan for the remainder of the project

Permission will be asked from the Italian integrator to publish a pilot dashboard on GitHub and the DECIDE web page. If permission is not granted, then a tool with mock data could be published. The Tableau notebook, together with documentation, is expected to be available online in the first quarter of 2025. There is no evaluation planned for this tool.

The work on the prediction model for footpad lesions will be published. The plan is to submit an article for publication in a scientific journal in the first quarter of 2025.

5.3 SalmonSyS – Norway

5.3.1 Context

SalmonSyS stands for “salmon syndromic surveillance” and is a tool prototype developed with the goal of incorporating mortality in salmon farms as a syndromic indicator for an early warning system.

Mortality is an important indicator of fish health and welfare in salmon aquaculture. In countries that are major producers of captive salmon, high mortality rates are a significant challenge. In 2023, more than 58 million fish died after being transferred for production in marine farms in Norway, which amounts to more than 3 out of 20 fish dying during the year. A range of factors, including disease outbreaks, environmental events such as algae blooms, and treatments aimed at controlling sea lice infestations, can contribute to the increased mortality of salmonids.

There is a need for improvements in how salmonid mortality information is provided for benchmarking. The presence of multiple data sources and storage formats presents a challenge to the integration, collation, and analysis of data, which are crucial for distributing information about salmon mortality and its determinants. Improvements in benchmarking may involve incorporating farm-level metrics of mortality based on mortality models, rather than using a more simplistic approach that evaluates mortality at regional or national levels. By continuously monitoring mortality data, valuable insights can be obtained for more effective farm management and disease surveillance.

5.3.2 User category/categories

SalmonSyS has been designed to supply to a diverse range of potential users, including salmon farmers, the private sector (veterinarians, fish biologists, vaccine companies, etc.), and the public sector (such as the Norwegian food safety authority, the Norwegian directories of fisheries, the Norwegian Veterinary Institute (NVI), and other research institutions). Since the tool includes farm-level data that is displayed without aggregation and may be sensitive, any future development of SalmonSyS may need to restrict access to users with specific data agreements.

5.3.3 Data source

The data used in the tool comes from various sources, including farm management systems at aquaculture sites, databases maintained by laboratories and competent authorities. Farmers usually use web platforms for reporting production data to competent authorities. The Norwegian Veterinary Institute (NVI) can query data from sources it does not maintain or retrieve data in different formats when it is available (open data), e.g., from the Norwegian Directories of Fisheries (NDF) website: https://www.fiskeridir.no/Akvakultur.

The NDF is the source of data regarding farm registries, which include information such as geolocation and farm license type, stocking month, fish weight, number of stocked fish, and number of dead fish. The Norwegian Food Safety Authority (NFSA) maintains environmental data such as sea surface temperature, treatments data, and clinical records. Disease outbreak data and laboratory data are kept in NVI’s sample journal system database.

5.3.4 Tool architecture

The salmon tools’ pipeline is, broadly speaking, the system set up to consume, analyse, and present data at NVI. This is a semi-automated pipeline; parts of it run on a schedule, while other parts involve manual work. This pipeline follows three main dataflows. See the chart below for the steps described (Figure 41). It is worth mentioning that the pipeline developed for SalmonSyS has elements that could also be applicable for Lak-setap (section 3.4), although not every dataflow is shared between them.

The first part of the pipeline, involving NDF API, runs on the 21st of each month. It begins with authentication to the API. After successful authentication, an Azure function pulls the data and stores it in a database owned by NVI. An Azure function is a serverless computeR service that provides resources on demand. Once the data is stored in the database, it becomes available to researchers. The second part involves downloading XLSX or CSV files from specified data source websites. The goal is to streamline data collection and ensure access to the latest data for analysis. An R script retrieves files from predefined URLs and stores them in a local directory. The third provides access to data entered directly at NVI database.

The following steps are primarily manual. Researchers log in to the database and explore the data. The final product is a master table containing the required data, which serves as a source for producing summaries by species, time periods (months/weeks/days), and other metrics. These summary tables are then used down-stream by other researchers to generate various summaries, including mortality rates and multiple predictors necessary for running a mortality model.

The mortality summaries, along with the model results and early warning system outcomes, are stored in a table, which is then fed into an RMarkdown script. This script was developed using the flexdashboard, plotly, dygraphs, and tmap R packages, enabling the creation of interactive data visualizations. The final product is currently delivered as an HTML document.

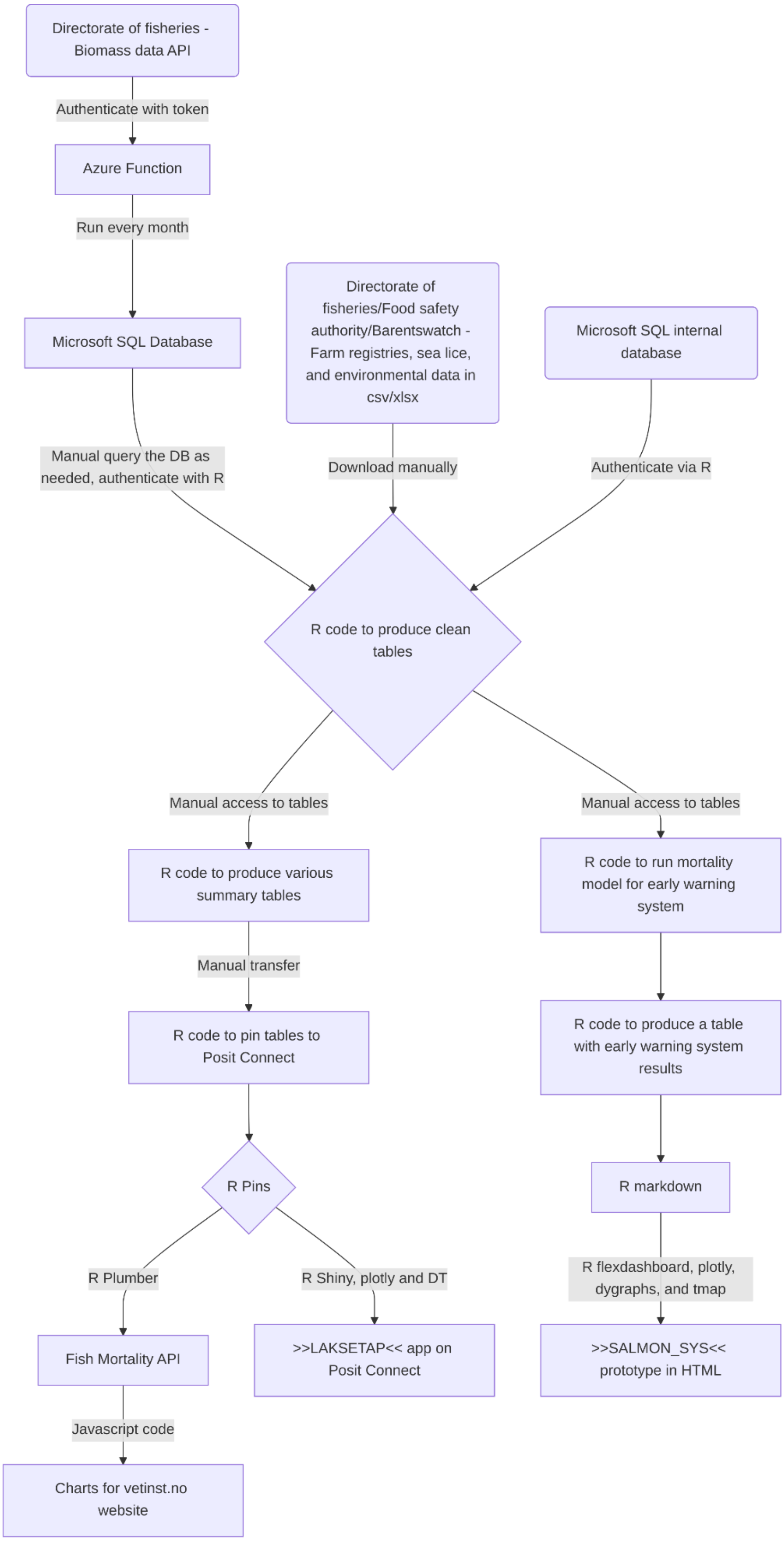


Figure 41. Chart to illustrate the pipeline and dataflow for SalmonSyS.

5.3.5 User interface (including screenshot)

Figure 42 to Figure 44 show screenshots of the SalmonSyS dashboard prototype. The dashboard consists of four tabs, each serving a specific purpose, as explained below under "5.3.6 Content and Functions".

5.3.6 Content and functions

In the first tab (Figure 42), users are presented with a snapshot of data for a particular month. It includes the number of active farms during that month, as well as farms categorized by their mortality levels: those above 2% (non-baseline levels) and those below 2% (baseline levels). Additionally, a map displays the geographical distribution of farms based on their mortality levels across Norwegian coastal waters.

The second tab, not depicted due to sensitive data, offers further details regarding farms with mortality above 2%. Users can observe the duration of elevated mortality levels through a gradient colour palette that represents alert levels. Moreover, an interactive map allows users to click on specific farm markers to investigate potential factors contributing to high mortality, such as disease outbreaks and the number of sea lice treatments.

The third tab of the dashboard replicates similar functionalities to those in the second tab. It includes another map displaying factors associated with mortality, specifically for farms with registered mortality at baseline levels. Additionally, this tab contains a time series graph illustrating current and historical mortality distribution at both national and regional levels (Figure 43).

The fourth tab provides a time series view, focusing on the expected versus observed mortality for individual farms throughout the production cycle. When observed mortality surpasses the upper limit of expected mortality, as determined by a mortality model, it serves as an early warning of potential adverse events at a farm (Figure 44). A study evaluating the performance of an early warning system in detecting outbreaks of salmon pancreas disease has been published (https://onlinelibrary.wiley.com/doi/10.1155/2024/9861677).

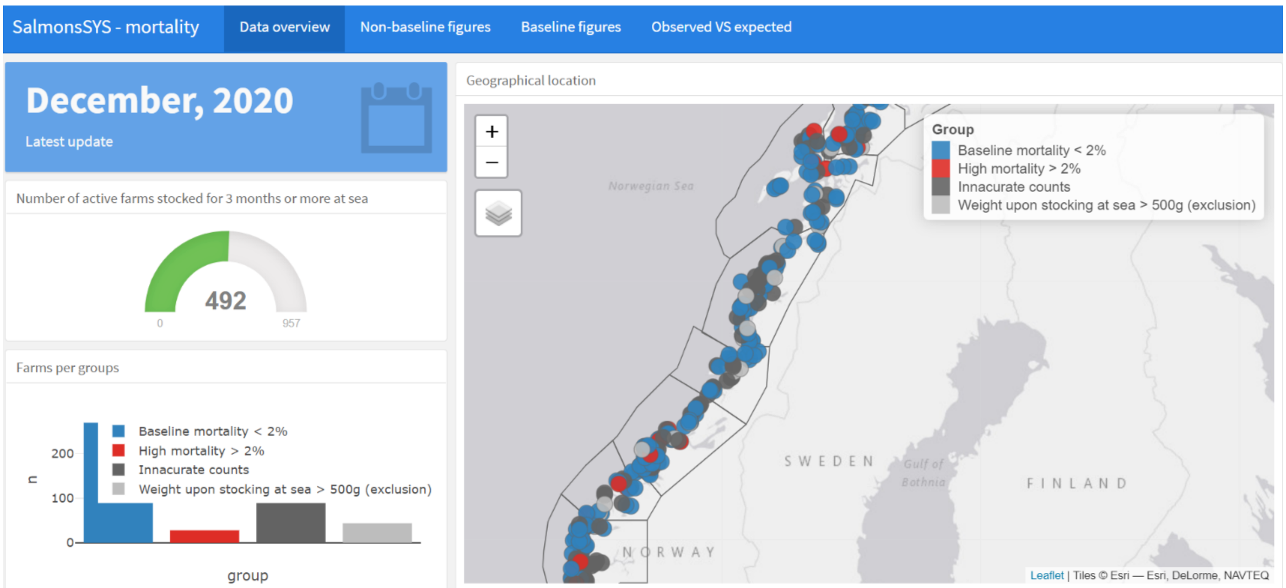


Figure 42. First tab of the SalmonSyS dashboard prototype.

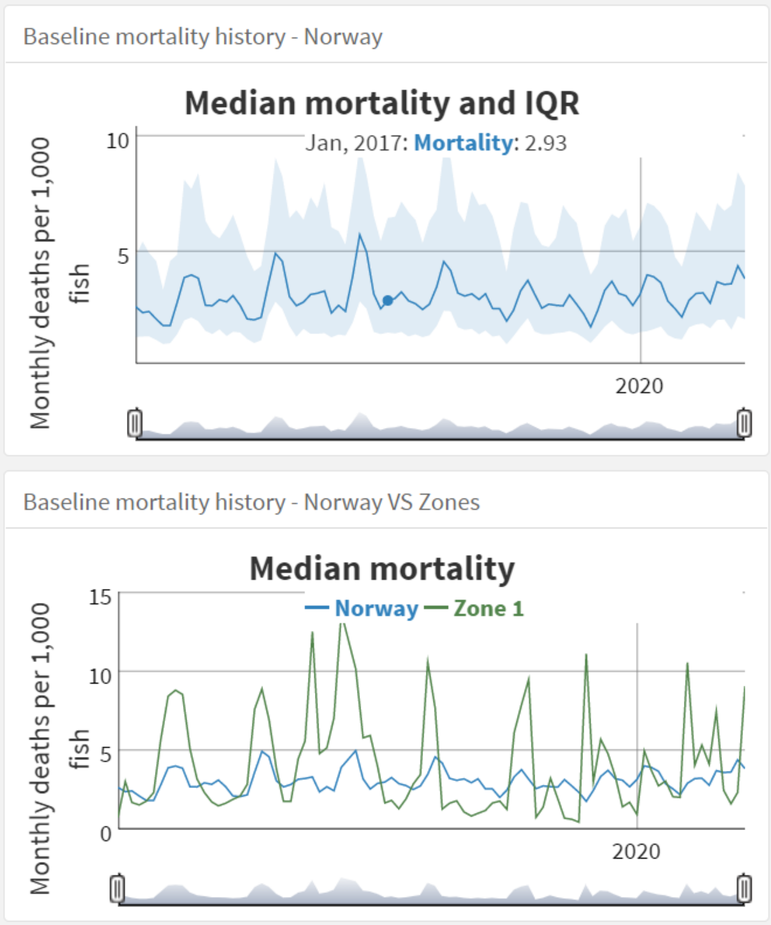


Figure 43. Time series plot of mortality in the third tab of SalmonSyS prototype.

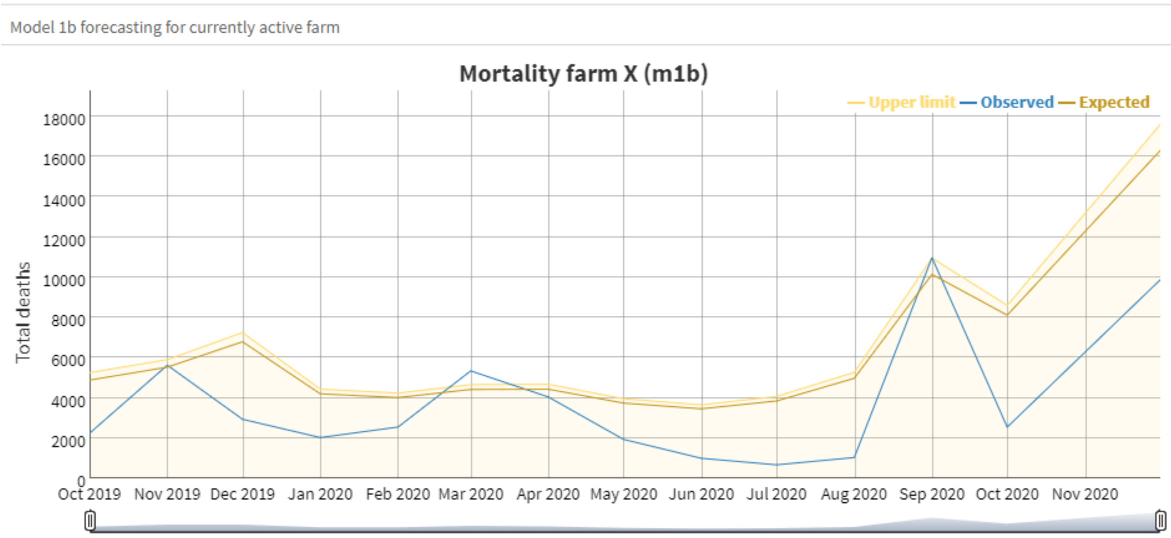


Figure 44. Time series plot for early warning system in the fourth tab of the SalmonSyS prototype.

5.3.7 Involvement of WPs

A focus group interview study, part of WP5, utilized SalmonSyS to showcasing and collect qualitative data. In WP1, a salmon ontology was developed using a dataset template; however, this ontology has not yet been tested with real data. Currently, we are building dynamic linear models (DLMs), based on the DLMs developed by WP2 with Scottish data, for early warning applications using Norwegian data. If time allows before the project concludes, we may integrate these models into the tool as an enhancement to the ones already running in the prototype.

5.3.8 Sustainability aspects

Continuation of this tool beyond the DECIDE project is under consideration. Data-sharing agreements pose a challenge for maintaining this tool with farm-level data in the long run. Still, the early warning system and the prototype developed could be valuable for incorporating certain features in a restricted-access tool that protects data confidentiality.

5.3.9 Plan for the remainder of the project

- Further development of dynamic linear models (WP2) with Norwegian data. Currently-June 2025.
- Update of the prototype based on stakeholders' feedback, pending feasibility and resource assessment. August-December 2025.
- Discussions with stakeholders to showcase updates of the tool prototype, pending feasibility and resource assessment. January-June 2026.

5.4 Early Disease Warning Pigs – Spain

5.4.1 Context

Early detection and diagnosis of disease in pig farming is critical for timely intervention, which potentially improves treatment success and reduces disease impact. Therefore, precision livestock farming (PLF) is potentially one of the most powerful avenues for decision-making based on real-time livestock management. There is precedence for combining different sensor data streams collected in livestock production for detection of, or fore warning about, disease events. At IRTA we aim to combine and integrate information from different farm sensor data to develop models capable of raising early warnings to occurrences of disease in growing pigs. Specifically, we are developing a model based on the drinking behaviour of growing pigs, for predicting events such as disease outbreaks, changes in the quality of feed, or ventilation problems, which often make the pigs' drinking behaviour deviate from the normal pattern.

5.4.2 User category/categories

Potential main users of early warnings based on water consumption are animal care takers (farmers), farm managers, veterinarians, producers and other health advisors. The R coding for modelling the drinking patterns and early warnings will be initially shared and tested with the data owner (data provider).

5.4.3 Data source

The data owner is a pig integration company named Vallcompanys Group. This enterprise owns a fattening farm named Farm 5.0 (watch video in Spanish at https://youtu.be/W27tdNt2eSg) that has different sensors implemented, including environmental (temperature, humidity, ammonia, CO_2), water and feed consumption, and cough sensors (SoundTalks®). Through a web service, the IRTA team makes calls for data and data are then downloadable in .csv files. Before data flows into a data repository, it undergoes cleaning and is prepared in R software to ensure appropriate data integration for subsequent modelling.

5.4.4 Tool architecture

An autoregressive moving-average (ARMA) model coded in R has been used to characterize the drinking behaviour of fattening pigs (Figure 5.4.1). Thus far, the predictions (red colour) fit well the real (blue colour) drinking pattern of pigs through the fattening period, as all real values fall within the 95% confidence intervals of the predictions. Moreover, the model accurately predicts the trend in increasing water consumption as the pigs grow and adapts properly to the observed seasonality. The final aim is to integrate this model into a computer-based system for further testing and validation of the model. Long-term solutions for data pipeline, software solutions and IT infrastructure are yet to be defined and discussed with the data owner.

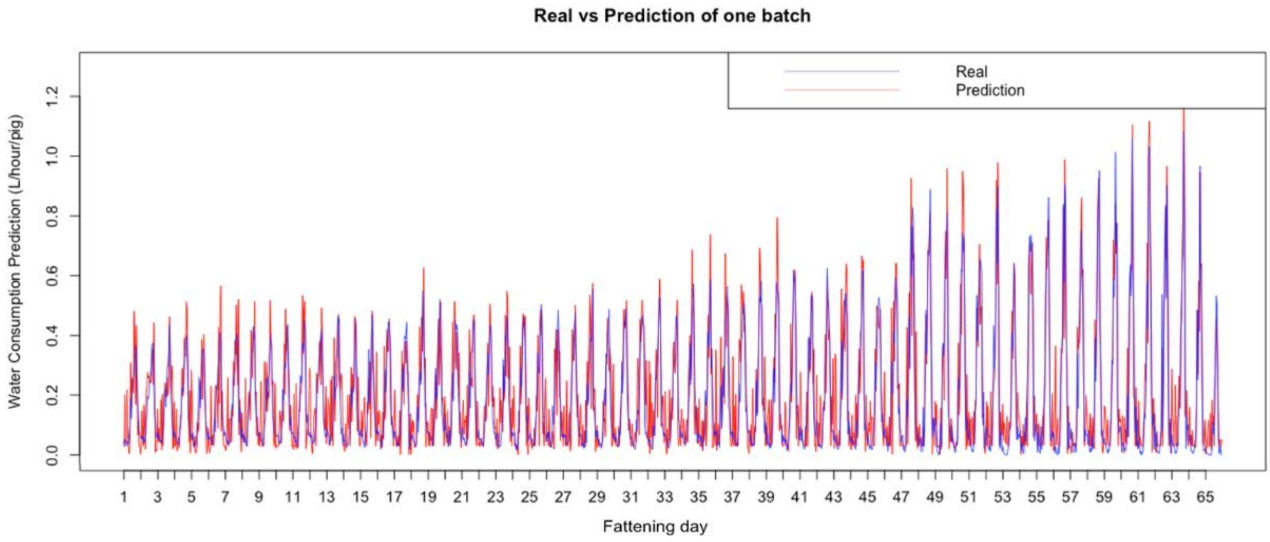


Figure 45. Prediction of the water consumption per pig (in red) against the real water intake (in blue) through the fattening period in one barn.

5.4.5 User interface

No user interface exists, and an early warning platform development is not foreseen within the DECIDE project. The R code will be provided to the data owner (Vallcompanys Group), so the model can be integrated into a computer-based system for further testing and validation in the Farm 5.0 and other farms of the company.

5.4.6 Content and functions

The data used to develop the model was collected at the barn level from several batches, from December 2020 to January 2023. Data from five consecutive batches from six barns (30 time series) of the fattening farm 5.0 were retrospectively collected and analysed. The final outcome is an ARMA model coded in R that makes forecasts of the hourly water consumption in fattening pigs (L/hour/pig). Next steps are including warning codes (i.e., distinguish deviations from the normal patterns of data). IRTA ambition is to provide and implement the R coding for data modelling and warnings directly on Vallcompanys data repositories, so the models can be tested and validated.

5.4.7 Involvement of WPs

For the Early Disease Warning, monitoring water consumption in fattening pigs was chosen because of the input received from the focus groups with vets as part of WP5. In addition, some of the aspects applied in time series analysis through dynamic linear models (DLM), as part of WP2, were adopted in the currently used model, which is an autoregressive moving-average (ARMA) model.

5.4.8 Sustainability aspects

There are no concrete plans for tool sustainability and development of a business plan is not contemplated within DECIDE. In later stages of tool development (and probably beyond DECIDE), the Valorisation Office of IRTA may be involved in the development of an overarching valorisation plan and a strategy to protect the intellectual property of the final R coding/algorithms.

5.4.9 Plan for the remainder of the project

The main goal is to integrate the model and warnings into a computer-based system property of the data owner – data provider, so that the model can be tested and implemented at the field level.

- Winter 2025: publication of the model in a peer-reviewed journal.
- Spring 2025: work on all the necessary information to make the code available in the GitHub repository.
- Summer 2025: integrate the model and warnings into a computer-based system.
- Fall 2025: adjust the code based on implementation outcomes.

5.5 Early Warning Calf Mortality – Norway, Sweden

5.5.1 Context

A high rate of calf mortality indicates poor welfare in dairy production and results in economic losses due to extra labour, increased replacement costs, and cadaver disposal. Although calf mortality in Sweden may be lower than in other countries, there is currently no analysis of temporal trends in calf mortality, which means that changes could go unnoticed. The purpose of the tool is to monitor monthly calf mortality and provide alarms when mortality is higher than expected. Our approach is to analyse the mortality data from different perspectives, using known risk factors (herd size, county) to examine the data.

Regular meetings are being held between SVA and Växa advisors to develop the tool in an iterative manner. Discussed topics are data interpretation and interpretation of model outputs. In the upcoming development stages, discussions with stakeholders will be focused on the selection of some use cases (i.e., BRSV outbreaks) for model validation and model fine tuning.

5.5.2 User category/categories

The anticipated users are dairy cattle farmers from Växa and their farm advisors and veterinarians, and experts from governmental organizations (SVA).

5.5.3 Data source

Växa is the provider of the calving data, production data, and mortality data used by the model. The data was derived from approximately 85% of all dairy cows, representing 79% of the dairy herds, and produced 87% of the milk (kg) in Sweden. For tool development during the proof-of-concept phase, Växa shared with SVA multiple .csv files extracted from their database containing data from all herds in the association from March 2016 to September 2021. The dataset is being used to develop codes to clean, organize, and analyse the data using R software for statistical computing.

The data is being analysed using a combination of Dynamic Linear Models and Dynamic Generalized Linear Models (WP2) with statistical quality control methods (Shewhart control charts, CuSum, etc.) for the generation of alarms. Currently, we are working on monthly analysis of mortality data in different age groups at different levels: herd, county, by herd size, and by amount of milk yield. However, weekly analysis of the data will also be explored.

5.5.4 Tool architecture

Long-term solutions for data pipelines are yet to be identified, and different software solutions and IT infrastructure will be identified depending on user's requirements. Depending on where the tool is hosted, monthly or weekly data will be collected, analysed, and reported.

5.5.5 User interface

During the development of the proof-of-concept, R software is being used. Access to the tool will depend on the identified long-term hosting solution.

5.5.6 Content and functions

The plan is that users will be able to look at different graphs showing the evolution of mortality data over time. Depending on which models are found to be effective, model output may be monthly or weekly, and these could be presented for individual herd IDs, or aggregated by county, or by certain herd characteristics such as herd size or milk yield.

5.5.7 Involvement of WPs

Focus groups conducted in Sweden with WP5 highlighted the need of early warning models from farmers. Currently, the tool is being developed in collaboration with WP2 as the dynamic linear model (DLM) framework constitutes the core of the tool.

Due to the early development stage of this tool, the inclusion of disease burden estimations (WP4) is not foreseen. Collaboration with WP1 is expected for the elaboration of the tool metadata.

5.5.8 Sustainability aspects

How the tool will be maintained, used, or further developed has yet to be discussed with stakeholders.

5.5.9 Plan for the remainder of the project

- December 2024: finish multivariate DGLMs with mortality data aggregated by county or by herd size.
- January 2025 - March 2025: work on hierarchical multivariate DGLMs for individual herds within counties.
- March 2025: present results to Växa and agree with stakeholders on a case study for a specific disease to validate the model. Define stakeholder requirements that will be used to guide the next development stage.
- April 2025 - December 2025: work on selected case study for model validation.
- December 2025: present results from model validation to stakeholders. Develop a plan for tool sustainability.
- January 2026 – June 2026: work on tool implementation and tool documentation. Generate all the necessary information to make the tool available in the GitHub repository. Dissemination of results to scientific community and farm advisors and veterinarians.

6 Prototype descriptions – tools where development is paused

6.1 Purchase Risk Meter – Sweden

6.1.1 Context

In Sweden, there is a National Surveillance program for *Salmonella* in place since 1995, when the country joined the European Union and was granted additional guarantees for *Salmonella*. If a herd is found to be *Salmonella* infected, the farmer can be economically compensated. However, in order to receive such compensation, the herd must meet some requirements, one of which is what is known as the 150-5 rule. This rule states that farmers trading live cattle with other herds should not buy more than 150 animals from 5 different herds for any given year. In 2022, the Swedish Veterinary Agency (SVA) and the Swedish Board of Agriculture received the mandate from the Swedish government to review the National Surveillance program for *Salmonella*. As part of this review, SVA proposed to substitute the 150-5 rule with an output-based method and a tool known as the "Purchase Risk Meter" to be used among cattle farmers. In this tool, county-level within- and between-herd prevalences estimated from the active surveillance testing are used to estimate the probability of introducing *Salmonella* in a herd when buying cattle, given the number of animals purchased and the origin of the selling herd(s).

Currently, this tool uses data from Sweden to be used on cattle herds. However, it can easily be adapted to other countries and livestock species with similar data on *Salmonella* or other pathogens.

6.1.2 User category/categories

Cattle farmers, farm advisors, trade brokers, the Swedish Board of Agriculture, veterinary advisors (SVA).

6.1.3 Data source

The tool uses input from the users (numbers of animals that they plan to buy, and the regional origin of animals/herds) and combines this with information at SVA on *Salmonella* seroprevalence (National Surveillance Program for *Salmonella* testing). Seroprevalence for each region is hard coded in the application and updated every time new samples are analysed in the framework of the national surveillance program (every three years, approximately).

6.1.4 Tool architecture

There has been no work to establish or describe the architecture of this tool, as development was paused at an early stage.

6.1.5 User interface

R Shiny application located in an R Shiny server hosted at and maintained by SVA. So far in the development, the server is set up for internal access only. For the application to be used outside SVA, we will need an externally accessible server.

6.1.6 Content and functions

Figure 46 shows a screenshot of the dashboard. The user enters the number of animals purchased from a given herd (**a**) and selects the county of the herd of origin from a drop-down menu containing all the counties in Sweden (**b**). Each purchase is saved as a row in a table that can be visualized by the user (**c**), and multiple entries (multiple purchases) are allowed. Alternatively, an .xlsx or .csv file containing the same information (county and number of purchased animals) can be uploaded by the user (**d**), and the table with all the purchases can also be downloaded by the user. The user interface returns the probability (%) of introducing at least one positive animal from at least one of the selling herds (**e**). It also contains a gauge plot where indicates the overall probability as well as an assigned colour (red, yellow, green) corresponding to the acceptable level of risk. The probability and the colours of the gauge plot also match an icon of a smiley face that changes colour according to the colours of the gauge plot (**f**). In the future, other tabs will be added to the app such as maps, interpretation of results, or recommendations on how to reduce the risk of introduction of *Salmonella* (**g**).

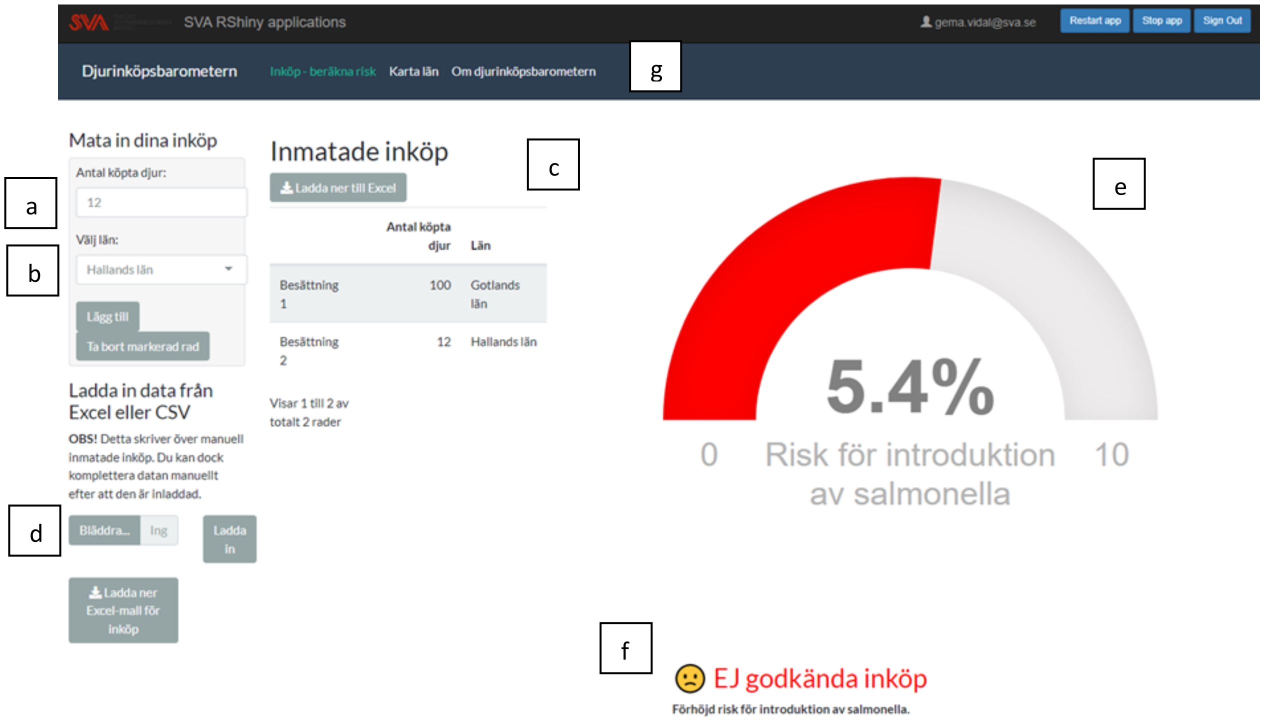


Figure 46. Screenshot of the Purchase Risk Meter tool, developed by SVA (SE). a) Number of animals to be purchased; b) County where the selling herd is located; c) Number of animals and county of origin for each one of the purchases entered by user; d) Upload/download of information entered by the user; e) and f) Visual representations of the output calculated by the tool; g) Other tabs with information to be developed in the future.

6.1.7 Involvement of WPs

WP5 has been involved to investigate stakeholders' use and need of on-farm technology in animal health work. Development of this tool is paused as we are waiting for further directions from the Swedish Board of Agriculture. If development is resumed, we foresee the involvement of other WPs.

6.1.8 Sustainability aspects

Revision of the National Surveillance Program for Salmonella is ongoing. This is a slow process that spans over several years and includes all involved authorities, animal health organisations and different industry representatives. It is not known at this stage if the 150-5 rule will be replaced or not. In other words, it is not known if alternative approaches will be needed, and who would be responsible for a potential tool.

6.1.9 Plan for remainder of the project

Because the need for a purchase tool in the Salmonella surveillance program is not known, we have paused further development of the tool.

6.2 Lely Calf Health Support Tool

6.2.1 Context

At this moment Lely has four test herds in which they test newly developed sensing techniques. Techniques that show promising results are daily camera visualization of calves for growth monitoring, audio recording of coughing to monitor respiratory health, and data resulting from the automatic calf feeder to monitor feeding behaviour. The purpose of these sensing techniques is to detect deviations in feeding behaviour and to detect (pre-)clinical signs as a result of respiratory infections such as BRD, *Mycoplasma bovis* or *Mannheimia* *haemolitica*. The value of early detection of such deviations increases when the farmer has the tools to identify the causative agent and subsequently, identify relevant measures to prevent further and future infections in the herd.

6.2.2 User category/categories

Dairy cattle farmers.

6.2.3 Data source

The tool uses sensor data that is generated by automatic calf feeders in pens of group housed dairy calves. The data for the prototype originates from four dairy farms that are affiliated to Lely who use the calf feeders. For the prototype development, data from these four farms from Sept-Dec 2023 is used to develop the aberration detection model.

6.2.4 Tool architecture

In the tool it is foreseen that an algorithm gives automated signals to the farmer when sensors indicate an aberration in individual feeding behaviour (preferably combined with activity). For detection of aberrations Dynamic Linear Models are developed (WP2) on the data from calves labelled as healthy or diseased. In this model, data on drinking behaviour (drinking speed, consumed litres) from healthy pre-weaned calves (i.e. without fever and clinical signs indicative of respiratory disease) serve as a basis to detect outliers in drinking behaviour in calves that are potentially sick. The model would generate a signal to alert the farmer that a specific calf needs attention. The idea is that based on this signal, the farmer or vet takes a sample from a sample of calves in the pen including the one showing aberrations in the individual indicator and submits it to a veterinary laboratory. The lab runs a predefined set of diagnostics on most prevalent respiratory pathogens and returns the test results to the tool. The tool automatically informs the farmer about the pathogen involved and the most effective intervention measures to be taken to prevent further spread of the pathogen in the short term and recursion of the pathogen in the long term.

Long-term solutions for data pipelines are yet to be identified, and different software solutions and IT infrastructure will be identified depending on user's technical requirements.

6.2.5 User interface

Not yet developed but this is foreseen in the existing Lely Horizon app, which is already used by dairy farmers to access their farm management data (performance of dairy cows and their calves). At the moment however, it is not yet certain that the early detection model will be sufficiently valid for eventual implementation in the tool.

6.2.6 Content and functions

Not yet developed.

6.2.7 Involvement of WPs

Model development has been performed in collaboration with partners in WP2. So far this has not led yet to a model that performs sufficiently in generating timely signals for calves with known health issues. Partners in WP4 are involved to explore if economic and welfare aspects of early warning signals could be incorporated in the decision making by farmers.

6.2.8 Sustainability aspects

The anticipated tool will be highly sustainable when embedded in Lely Horizon. Lely operates worldwide and therefore easy access to other parts of Europe and the rest of the world is within reach.

6.2.9 Plan for the remainder of the project

- Oct-Dec 2024: finish model development phase based on pilot study data (Autumn 2023)
- Go/No-Go for further development based on model performance to distinguish sick and healthy calves using their drinking behaviour.