MOOD

Monitoring Outbreak events or Disease surveillance in a data science context

Project number: 874850

Horizon 2020

SC1-BHC-13-2019

Type of action: RIA

Deliverable D.1.4

Title: Report on the learning loops fostering the utility of social and technical innovations

Due date of deliverable: 30/11/2023

Revised due date of deliverable: 31/12/2023

Actual submission date: 21/12/2023

Start date of the project: January 1st, 2020 **Duration: 60 Months**

Leader of the Deliverable: GERDAL

Dissemination Level	
PU Public	X
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

Project Information	
Project Acronym	MOOD
Project Full Title	MOnitoring Outbreak events for Disease surveillance in a data science context
Name of the funder	European Commission – H2020
Call Identifier	H2020-SC1-2019-Single-Stage-RTD
Topic of the call	SC1-BHC-13-2019 Mining big data for early detection of infectious disease threats driven by climate change and other factors
Grant Agreement Number	874850
Project Duration (YYYY/MM - YYYY/MM)	2020/01/01 – 2024/12/31
Project coordinator (Name of institution)	CIRAD
Cirad Project scientific leader (name, RU, e-mail)	Elena ARSEVSKA, ASTRE, elena.arsevska@cirad.fr
Project goals	MOOD aims at using state of the art data mining and data analytical techniques of disease data, Big data, and contextual data originating from multiple sources to improve detection, monitoring, and assessment of emerging infectious diseases (EID) in Europe. MOOD will establish a platform for mapping and assessment of epidemiological and genetic data in combination with environmental and socio-economic covariates in an integrated inter-sectorial, interdisciplinary, One health approach. More precisely, MOOD will develop: 1. The epidemic Intelligence community of practice to identify user needs of end-users i.e. national and international human and veterinary public health organizations; 2. Data mining methods for collecting and combining heterogeneous Big data; 3. A network of disease experts to define drivers of disease emergence; 4. Data analysis methods applied to the Big data to model disease emergence and spread; 5. Ready-to-use online platform tailored to the needs of the-end users and complimented with capacity building and network of disease experts to facilitate risk assessment of detected signals. MOOD outputs will be co-constructed with end-users at public health agencies to assure their routine use during and beyond project duration. They will be tested and fine-tuned on a set of air-borne, vector-borne, multiple-transmission route diseases, including anti-microbial resistance and disease X. Extensive interactions with end-users, studies into the barriers to data sharing, dissemination and training activities and monitoring of the impacts and innovations of MOOD outputs will support future sustainable use.
Key words	Infectious diseases, big data, epidemic intelligence, one health, impact, environmental changes, climate changes, user needs, socio-technical innovation
Project partners (Name of institutions)	CIRAD, ITM, FEM, ETH, INESC ID, ERGO, SIB, INSERM, ULB, KU LEUVEN, UM, SOTON, AVIA-GIS, MUNDIALIS, OPENGEOHUB, UOXF, ISS, THL, GERDAL, IPHS, ISCIII, ANSES, INRAE, ISID

Executive Summary

The MOOD project has chosen to take into account the needs of innovation of the PH and AH agencies in Europe in order to support the change of practices that will improve the epidemio-surveillance and early warning of Emerging Infectious Diseases.

The initial user needs assessment showed a wide range of general expected changes of practices involving multiple dimensions (technical, organisational, legal, ethical, financial). A strategy of case studies has been chosen to organize the interactions with practitioners in order to adapt the technical requirements to their needs and provide support (through communication, strengthening of capacities).

In this deliverable, we will see how this strategy has been implemented, to which extend, and which role it played into the socio-technical innovation process. Although the core concern of the researchers was the scientific validity of their outputs, the exchanges with externals (Ei practitioners and academics) allowed to identify the useful covariates and standardization; to discuss the wanted outputs, the data availability and access, the data management (data protection, repository, updating) and ergonomics. Some testing and collective exchanges are still needed concerning the uses and ergonomics at the scale of the platform (integration of the tools).

Our identification of the innovations corresponds to an ex ante approach of what will be the probable uses of the tools leading to probable changes of practices if the expectations in term of the addition of new functionalities and improvements will be taken into account as planned in 2024.

Keywords

Co-creation, innovation, outputs, outcomes, strategy, sociology

Document History

Date	Revision	Comment	Author/Editor	Affiliation
22/09/23	V1	Draft of the plan	Fanny Bouyer	GERDAL
03/10/23	V2	editing	Fanny Bouyer	GERDAL
10/10/23	V3	editing	Fanny Bouyer	GERDAL
12/10/23	V4	editing	Fanny Bouyer	GERDAL
20/10/23	V5	editing	Fanny Bouyer	GERDAL
24/10/23	V6	editing	Fanny Bouyer	GERDAL
25/10/2023	V6	reviewing/editing	Timothée Dub	THL
03/11/23	V6bis	review	Fanny Bouyer	GERDAL
15/11/23	V6bis	review	Wim Van Bortel	ITM
17/11/2023	V7	editing	Fanny Bouyer	GERDAL

20/11/2023	V7	editing	Pierrine Didier	INRAE
30/11/23; 01/12/23; 05/12/23	V8	Editing and review	Fanny Bouyer	GERDAL
13/12/23; 14/12/23; 15/12/23; 18/12/23	V9	Editing and revision	Fanny Bouyer	GERDAL
19/12/23; 20/12/23	V10	Editing and revision	Fanny Bouyer	GERDAL
21/12/23	V10	Revision	Pierrine Didier	INRAE
21/12/23	V10	Revision	Fanny Bouyer	GERDAL

Abbreviations

AH	Animal Health
AMR	Anti-microbial Resistance
BRT	Boosted Regression Trees
Covid-19	coronavirus disease of 2019.” The World Health Organization (WHO) named the virus that causes COVID-19 “severe acute respiratory syndrome 2” or SARS-CoV-2.
D…	Deliverable
EB	Executive board
EBS	Event-based surveillance
EC	European Commission
ECDC	European Centre for Disease Control
EDE	Epidemiological Data Explorer
EI	Epidemic Intelligence
EpiDCA	adaptation of the Dendritic Cells Algorithm (DCA), inspired by the danger theory (Greensmith et al., 2008)
GA	General Assembly
GLM	Generalised Linear Models
HPAI	Highly Pathogenic Avian Influenza
IBS	Indicator-based surveillance
INLA	The integrated nested Laplace approximation is a method for approximate Bayesian inference.
LPAI	Lowly Pathogenic Avian Influenza
MOOD	Monitoring Outbreak events or Disease surveillance in a data science context (project)
NUTS	Nomenclature of territorial units for statistics, abbreviated NUTS (from the French version *Nomenclature des Unités territoriales statistiques*)
PADI-web	Platform for Automated extraction of Disease Information from the web
PH	Public Health
Pro-MED	International Society for Infectious Diseases
TCL	Transition Commitment Levels
TBE	Tick-borne encephalitis
TL meeting	Task leaders meeting
TRL	Technology Readiness Level
WNV	West Nile Virus
WP	Workpackage

Introduction

The ambition of the MOOD project is to produce numeric tools and services with a direct and sustainable impact on the epidemic intelligence practices and performances. This applied research encompasses an initial user needs assessment followed by a complex step of participatory development of tools i.e., “learning loops”. To understand how this process has been implemented and which roles did the chosen strategy play on the social and technical dimensions of the innovations, we have analysed 2 deliverables (D1.1 Report on user needs assessment, D7.5 Report on innovation and impact pathways), the framework notes concerning the organisation of these learning loops and 30 reports of meetings involving the potential end-users. Concerning the identification of the innovations, we used the results of online questionnaires filled by the participants of the testing sessions of the GA 2023.

1. Context of the implementation of the learning loops

1.1 Objectives of the project and stakes

MOOD project aims at **strengthening international and national PH/AH institutions** in Europe to be better informed and prepared about potential disease drivers and impacts of climate change on disease emergence, and to assess risks more effectively. For that matter, MOOD project produces digital tools and services based on the needs of the end-users. In the medium term, changes in knowledge and practices will contribute to a more efficient response to infectious disease threats, more adapted prevention, surveillance and control strategies, policies and measures at national and international levels, and improve Public and Animal health practitioners’ interventions. In the longer term, those changes will contribute to improve EU preparedness to emerging infectious disease threats, and improve human and animal health and welfare.

The strategy proposed to reach the objectives is based on the **participation** of the stakeholders (researchers and EI practitioners) in an impact-oriented project management and an approach of co-creation, together with the end-users in order to develop innovative open-source or publicly available digital tools and services for the early detection, assessment, and monitoring of current and potential infectious disease threats in Europe. Also, the innovations should consider and address the challenges of cross-sectoral data sharing and common analysis in a One Health framework.

The **general planned workflow** of MOOD (Figure 1) is based on the required data-flow: identification and collection of health and covariates data (WP2), to the data processing (WP3-standardization and integration), then modelling and analysis of big data (WP4) up to the development of tools (WP5). WP1 aims to analyse the user needs and facilitates the user validation and feedback across the different steps of design of the MOOD tools and services for epidemic intelligence. WP6 is in charge of capacity strengthening of the users and dissemination of the tools.

The workflow of the conception of MOOD tools and services is grounded in the planned data-flow and the transversal interactions including methodological support for facilitation, support to organize, monitoring of the impact, technical monitoring, communication (Figure 1).

The expected **major outputs** of the project are:

- **new digital tools and services:** maps, models, data collection tools for analysis and decision support. In addition, the development of data exchange platforms useful for the early detection, monitoring and assessment of risks of emerging infectious disease is intended;
- the **increase of capacities of stakeholders** at public and animal health agencies to improve their epidemiological data management practices to better detect and manage the risk associated with emerging infectious diseases.

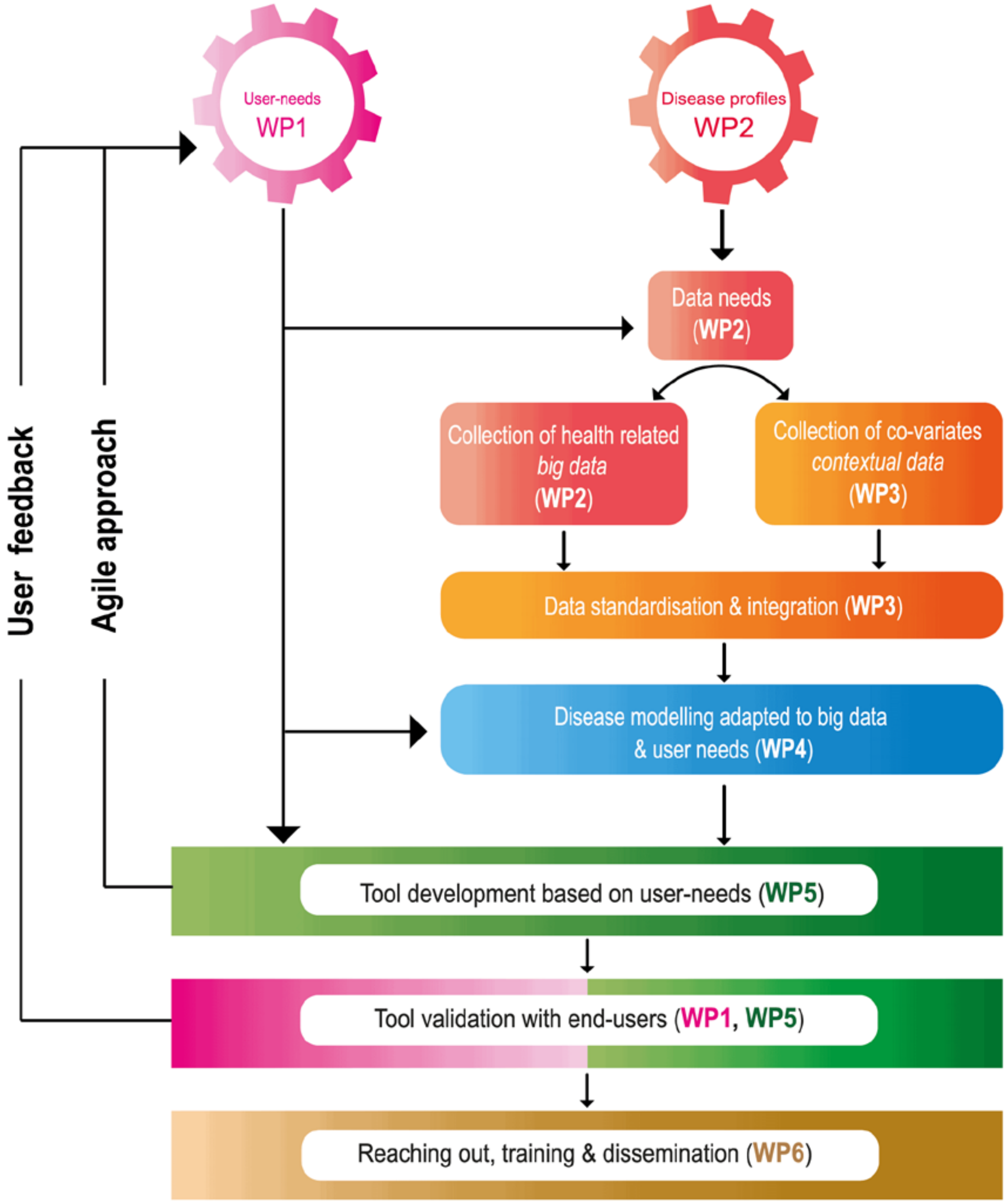

Figure 1. General workflow of the MOOD consortium

Effective innovation i.e., translated into effective changes in stakeholders' practices, is based on broader practical changes rather than the simple production of technical tools. It includes on the one hand the use of new tools adapted to stakeholders' needs, and on the other hand changes of the ways of working, of the organisation and relations between stakeholders. The initial user needs assessment considers these **multiple dimensions of socio-technical innovations** (See Box 1).

The notion of socio-technical innovation reflects this two-fold dimension of innovation. It encompasses a process of evolution of the practices and knowledge on which innovations are based, which goes hand in hand with changes in the modes of relationship and organisation within a professional field, which professional field includes several interacting professions.

The end users of the MOOD project are professionals who have an official infectious disease surveillance mandate at national and European level i.e., surveillance professionals working in public and veterinary health agencies and their direct collaborators (epidemiologists, modelers, disease specialists, biologists from reference laboratories) at national or European level, as well as the national representatives (or spokespersons) of professionals who regularly use surveillance outputs (such as decision makers in ministries).

ECDC has been early (by the call)[1] identified as one of the main users of the MOOD innovations as they conduct Epidemic intelligence activities and disseminate information to European countries who rely on ECDC for Event Based Surveillance (EBS), and are responsible for guidance and strengthening of capacities of the European Member States. In addition, due to the emerging COVID-19 pandemic and its first wave in March 2020 (early at project start), the European Commission (EC) requested the MOOD coordination to reorient where possible the project activities in the framework of the COVID-19 response in close collaboration with ECDC and European national PH agencies.

For users, it is necessary that the tools are:

1- Adapted to their needs (Box 1) i.e., responding in an efficient and relevant way to the problems brought up during the identification of the needs.
2- Sustainable, which implies that they are operational and integrated into the reality of their activities and working conditions in a sustainable manner.

The ambition was therefore to articulate a scientific validity of the tools that will be produced and an effectiveness of their use in a given professional environment. For that purpose, a strategy of co-creation process has been based on a participatory assessment of the EI practitioners' needs followed by 2-3 years of development of tools called "**learning loops**" during which the needs are in-depth defined, the specifications of tools discussed with users, the prototypes are tested in real conditions and the useful strengthening of capacities identified.

We define co-creation as the active involvement of developers of a specific solution or initiative and future end-users, from the exploration and articulation of problems or needs to the creation, implementation and evaluation of solutions or initiatives (Voorberg et al 2015; Vargas et al 2022).

The logic of the work-flow is based on the concept that the tools requiring modelling (such as the risk maps module) are produced by the WP4 and the interface implemented by WP5 through a dedicated platform centralizing all the tools; the scientific outputs are many and their production has been defined in the MOOD proposal though the tasks and subtasks of every WP. This description and the

[1] "The successful proposal(s) should foresee to consult with the end-users at both national (e.g. public health institutes) and European (e.g. ECDC, EFSA) level at key milestones of the project's timeline"

human resources allocated in this proposal set a first framework for the kind of tools that could be produced. The flexibility to adapt the tools was very variable according to the definition of the tasks: the main modules have been in itinere adapted in relation with the expressed needs of the practitioners (Cf. 2.2), but the mapping of AMR based on literature review has been implemented with no input of the practitioners until the release of the final prototype.

BOX 1. Theoretical Framework of the participatory user needs assessment

What do users' needs mean? These are expectations and areas for improvement that are expressed in relation to, or in response to, problems and concerns encountered in the professional activities of users. The **starting point for the identification of needs is therefore the users' own analyses of their situations:** what works well, the difficulties they encounter and what needs to be improved.

"The problems are not given by the situations but by those who experience them"(Darré, 2006).

These concerns are translated into issues to be addressed. It is not necessarily possible to formulate a direct need in relation to these problems, since the response is often multi-factorial.

The sociology developed by GERDAL postulates that innovation, which can either start with a change in practice or a change in design, refers to a process of knowledge generation that takes place in and through dialogue. First al all, this dialogue is between peers, who have common activities and shared professional reference system ("system of standards", of ways of working, which is nevertheless made up of variants), but also with their stakeholders who often have different points of view. These peer relationships can be more or less formalized within a network or group (e.g., a team in an institution, network of experts around a particular object). Faced with a problem to be solved, each one mobilises his/her dialogue network(s) in a specific way: the mobilized interlocutors and the scale of dialogue is specific to the type of problems. There are important variations in the forms and density of relationships, in the degree of structuring of dialogue networks, in other words, not everyone is placed in the same way with regard to access to cognitive and social resources to solve a problem.

Thus, we want not only to identify the "problems to be solved", but also to identify professional networks, including relationships between peers (as defined above) or with more distant stakeholders, at different scales, and to characterize these networks according to the different types of activities and their relationship to epidemiological data within epidemiological surveillance systems at the national level. Understanding the current problem-solving strategies of actors will make it possible to organize the support process and their active enrolment as well as to develop and inform a monitoring and evaluation system for the project.

Comprehensive socio-technical analysis

The analysis focuses on the characterization of the users, an overview of their digital practices and norms associated, an identification of their priority concerns, difficulties and current problems seen according to their point of view.

This need assessment relies on the collection of end users' view on their professional attributes, their digital practices, their professional network and the main **difficulties** they encounter. The participatory diagnosis of difficulties will be in-depth discussed to understand the causes and ways to solve these difficulties according to their "norms" of work. On this basis, we interviewed them in order to understand the situation where they experience complex problems that they want to solve. We collected the attributes (not pre-defined) of the socio-technical solutions they want, but the needs (what needs to be done, a sequence of multiple actions and solutions) cannot generally be expressed directly. Indeed, users are confronted with complex problems, the solutions of which, are not necessarily a single factor, and are not necessarily linked only to the development of a tool. The process for defining a clear definition of needs (i.e. the type of responses, the "means" to be implemented: tools, organization modalities, data quality, interactions between actors, etc.) is collectively discussed between users and consortium partners during workshops (WS).

Concern, difficulties → problems to solve → complex needs

Identified and prioritized by users | *modifiable according to collective thinking* | concertation process

The enrolment of stakeholders in a process of effective and collective change requires:

1. that stakeholders find themselves in a situation where they can discuss problems encountered and needs for improvement. This presupposes that they can express their expectations (concerns and analysis of what needs to be improved), each according to their own point of view;
2. that their change strategy is appropriately supported i.e., by placing at the heart of the process the modes of reasoning of the stakeholders (with a view to changing conceptions and practices, as indicated above) rather than proposing a path based on external expert reasoning.

1.2 Strategy of the case studies

Starting point of the learning loops: the initial user needs assessment

The user need assessment was based on the crossed analysis of interviews with users working in epidemic intelligence (EI) at the PH/AH agencies in the five case study countries (Serbia, Italy, Spain, France and Finland) and at the ECDC. Overall, the analysis highlighted that the users want to review their EI strategy in order to enhance their preparedness for new and emerging disease outbreaks. This could be achieved through a prospective approach and the development of tools and services for risk detection and risk assessment and accompanied by monitoring of perceptions of health events and control measures. Users, also wanted to have an easier health data and covariates acquisition process (timely, validated or standardized) for international epidemic intelligence, and to have better indicator-based surveillance (IBS) dataflows at national level respecting data protection and homogenous information for epidemiological analysis. They expressed the need of harmonization of their data sources and procedures for risks assessment in order to be able to compare their results with other countries or institutes. They also highlighted the need to avoid complete automatization of analysis in order to keep control on the data (choosing their origins or using their own data), inputs and to be able to adapt parameters to versatile objectives.

The issues related to the analysis of the acquired data mainly concerned the timely integration of One Health (multi-sectoral) data and the determination of thresholds of risk and outbreaks for vector-borne diseases. AMR surveillance and early warning relies on IBS and the users wanted a better integration of data, a timely dataflow to explore causality links with health care (hospitals and private sector), antibiotics use in animals and the environment. The elaboration of a strategy for intersectoral analysis was needed as well as a better expertise in genomics (identification of emergent strains and data visualization).

A timely monitoring of the Covid-19 pandemic led to new expectations regarding the spatio-temporal analysis of clusters, the standardization of health data and specific "human behaviour and social" covariates in order to monitor the pandemics but also the way to monitor trust in health measures in order to forecast the compliance and possible changes of behaviour.

Overall, **the needs are multi-dimensional**, beyond the technical expectations (new tools for new functionalities), the EI practitioners want to increase their abilities in a sustainable way (new epidemiological knowledge, a better know how to manage data protection), expand their professional network to regularly review their EI strategy and objectives and reorganize their routine at the scale of the team by improving the ergonomics of their practices and save time on basic steps to develop other EI activities.

During the first assessment of the user needs and workshops concerning One Health, a consensus was reached to develop simultaneously two kinds of tools: generic or basic ones and advanced or specific ones.

1. The generic tools could correspond mainly to basic data acquisition and manipulation such as “basic tools to improve access of covariates” by users, or “basic tools like catalogues or repositories for the provision of covariates (to facilitate the retrieval and use of them), or mapping of the sources, and the third category “basic tools to combine covariates data with the disease data”.
2. The tools of second level will be built with users in order to answer to “more advanced requirements” with modelling and visual analytics. This second level was implemented through five case studies.

Organization of the co-creation process around the hybridation of the planned activities of the “learning loops” with a strategy based on study cases

The learning loops correspond to the step of tools development after the initial user needs assessment during which exchanges between end-users and partners should allow to define the detailed technical requirements and linked needs (such as training, share of information etc). These exchanges produce learnings on both sides during several cycles of interactions and prototypes production.

The initial user needs assessment allowed to reach a comprehensive view of needs (“high level”) with a wide range of expectations, a first sorting of what could be addressed by the project and paths of solutions without technical requirements (or just the early stages). In relation to the disease-specific objectives of surveillance, dataflows, and epidemiology, it appeared that the detailed needs should be further in-depth discussed by model-disease in order to define the technical requirements and support/ strengthening of capacities. As a matter of fact, the expectations are disease-specific (e.g., the stake to address the epidemics of HPAI and Covid-19 led to very specific new requests but the expectations of improvements are also specific for each epidemiological model, even in endemic stages), the dataflows and data access are also specific so the solutions must be discussed by model. Some similarities about the epidemiological concerns have been agreed between WNV and TBE: these case studies have been addressed in a parallel process (with regular methodological exchanges and common meetings).

The modalities of exchanges with EI practitioners during the learning loops were not initially defined. Moreover, during the two sessions for the impact pathway review (15 and 16/04/21), the partners stated that the review of the impact pathway could not be made in a generic way and that the outputs and outcomes should be precised by model disease.

Thus, a strategy based on study cases (see 2.1) was proposed and chosen to organize and ease the interactions with practitioners by model-disease during the learning loops to improve the tools development planned in many tasks (of WP2, WP3, and WP4), and also to ease the ex ante monitoring of the impact. The case studies would help to define the technical requirements.

2. Implementation of the learning loops

2.1 Organization

Validation of the new strategy

A first discussion with the EB was held the 29/04/21 to propose a way to structure the exchanges in the framework of case studies by model disease or health concern (AMR). The coordination and the WP1 partners prepared a framework note to precise the roles of each partner and structure the Research-action approach based on case studies. Some partners (responsible of generic module and modelers) worried about the additional time needed to implement these case studies, but the sociologists stated that the stake was more to organize the needed exchanges. The preparation of the GA 2021 and its implementation brought food for thought about the process of co-creation. The first observation was that the concrete description of the final tools was not so obvious for the researchers/developers when preparing their sessions of the GA. The second point was the online poll that revealed that the EI practitioners were both interested to be involved in meetings per disease and per generic activities but a higher number was interested by disease-model activities. These two points led to the validation of a structuration of the exchanges through case studies linked to disease models, while allowing the developers to continue consultations on generic tools. WP1 members supported by WP6 and WP7 colleagues worked on the framework note up to October 2021.

The initial set up

The framework note aimed to reach four objectives:

- Set up the MOOD case study groups and the methods of interaction between researchers and users of the tools produced by MOOD.
- Define the roles of the different case study members with creation of the new roles of “case facilitators”.
- Set up some guidelines for communication and dissemination to the public and end-users.
- Set the general timeline of activities.

Following the meeting with users on July 13, 2021, **five case studies were** set, and their facilitator identified in relation with their involvement in the model-specific activities:

1) Avian Influenza (facilitator: J. Artois, ULB then Maria Vincenti)
2) West Nile Virus (facilitator: A. Rizzoli, FEM/FBK)
3) Tick-borne encephalitis (facilitator: T. Dub, THL)
4) Covid-19 (facilitator: C. Poletto, INSERM, WP4 & S. Delicour, ULB)
5) Antimicrobial Resistance (facilitator: E. van Kleef, ITM)

Two additional case studies groups were proposed, i.e., Tularaemia-Leptospirosis (facilitator: E. Arsevska, CIRAD) and Zika-Dengue-Chikungunya (facilitator: E. Arsevska, CIRAD): they started respectively in January 2022 and November 2022.

The roles of facilitator and animation team, and the specific roles of existing positions (like communication manager, WP leader etc) have been specified in the framework of the case studies.

The case HPAI (already started) has been seen by the sociologist as an example of process grounded on the user needs and a time line model/ road map has been proposed.

A general organisation of the process by steps (Fig. 2) and a communication strategy has been proposed. The initial timeline model (diagram with steps) has been simplified (Fig.3) and used to show the progression in the process during internal meetings in 2022. The ambition was to be able to discuss on the problematics set by the practitioners in a holistic approach (Fig.4) rather than to focus directly on the technical requirements of the identified tools. This was difficult to implement as many outputs were already planned on scientific objectives, with some established constraints (generic tools, rules of data protection and data ownership).

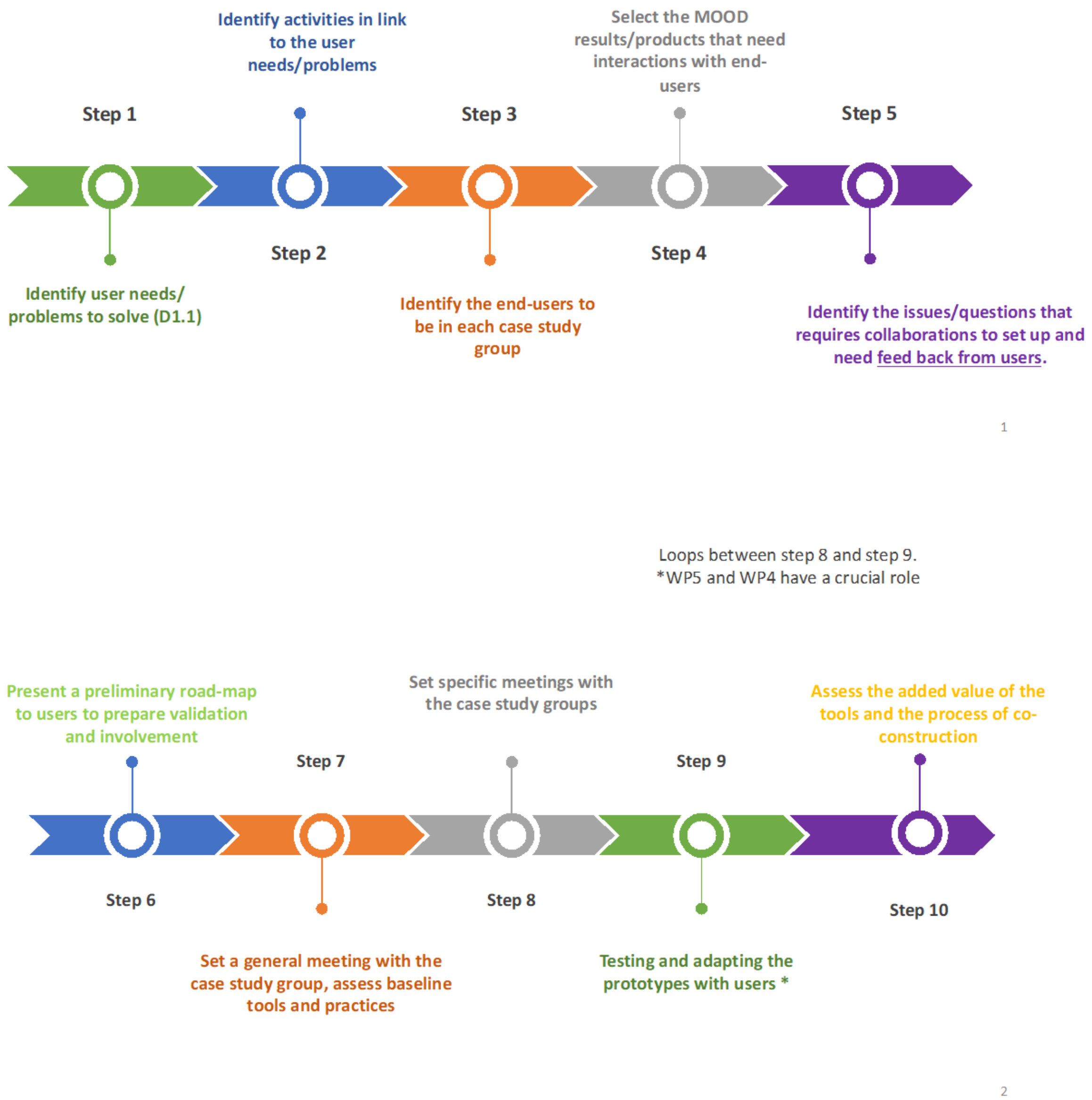

Fig. 2: Initial road map (generic time line) for the study cases

Fig. 3: Simplified road map/time line for the study cases

SOLUTIONS FOR WNV TO PROPOSE TO END-USERS: ONE TABLE BY TYPE OF PROBLEM

Which activities (precise sub-task)	Objective	Final tools to transfer to users (direct or indirect)	Collaborations to set up	Which points to discuss with End Users
Wint et al	Data provision for download and input for modelling	Visual platform in link with LIRMM	In link with LIRMM, ULB	Visualization functionalities, outliers, datasets from the users
Roche et al/ McKinon et al	Non-official data from media	N/A only data for models	ASAP provide Padi-web data (streams) as inut to the ULB models	N/A simply data provision
Engler et al	Data provision for WN phylogenetic analyses	N/A only data for models	ASAP provide data (streams) as inut to the ULB models	N/A simply data provision
Marini et al	Quantify past transmission risk using available data. Potential forecasting reliability to be assessed.	Expert work or analytical tool?	TBD	Developed models can be used to
Poncelet et al	Visualise which data or the models from Marine, Henaux and Erazo?	Needs of visualization must be precised by the end-users	In link with ERGO, ULB	New visualisations that can be useful to end Users
Henaux et al	?	Which differences of final use with risk mapping of Erazo and Dellicour or models of Marini?	TBD	To be discussed: for which uses?

Fig. 4: example of document used for the animation of the case studies (to organise the discussion around the final tools and the needed interactions with the EI practitioners/ potential users).

The actual set up

Gradually the partners preferred to use the TRL scale (Fig.5), an international reference for tool/technology development. The objectives of these tools are not the same: the timeline brings a guideline for the process of interaction, the TRL describes the progress of the tool.

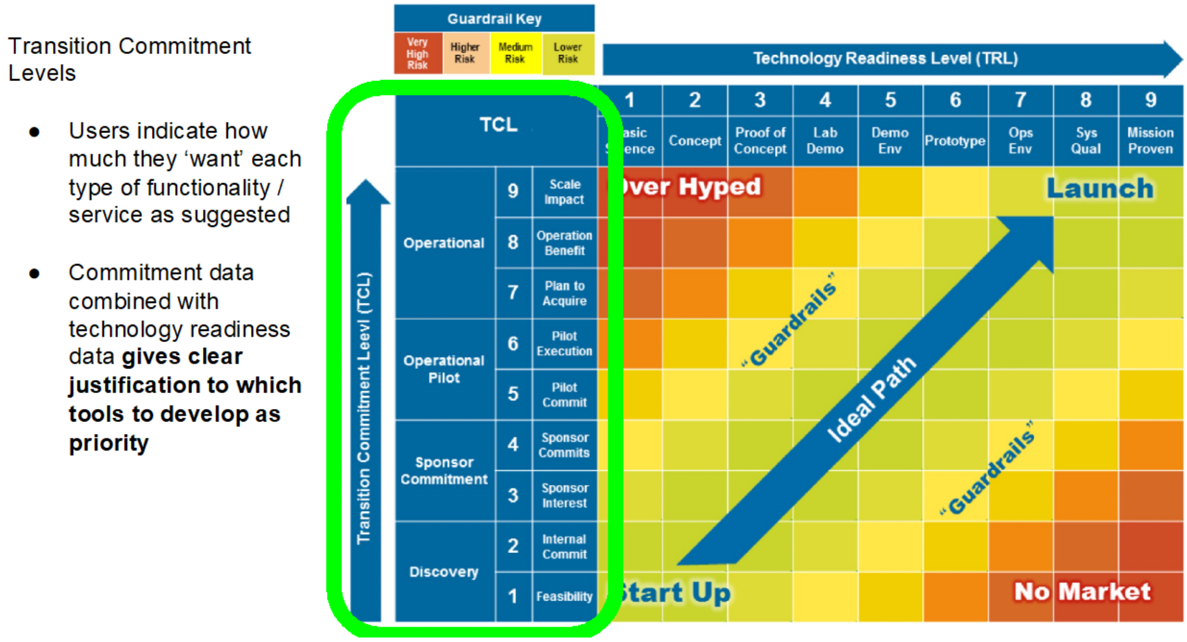

Fig. 5: Definitions and relation between Transition Commitment Levels (TCL) and Technology Readiness Level (TRL)

The three GA represented important steps of exchanges with practitioners. The GA of 2021 called "user consultation" was based on short presentation of the main types of tools that MOOD started to develop and prepared testimonials of EI practitioners about their expectations in term of tools and research outputs. Parallel sessions by case study were organised for the next GA of 2021 and 2022. The first test sessions have been implemented during the GA2023.

The MOOD coordination decided to plan regular meetings between the researchers/developers involved in the case studies: the so called "task leader (TL) meetings" were planned three times by year to discuss the issues related to the tool development, the progress of the case studies and the required workflow between WPs/partners, in addition to the WP meetings in which the scientific progress of the activities were discussed.

Some meetings between facilitators or between facilitator and developers have been organised to prepare each TL meeting. They were useful to share information about the workflow, exchange between peers about what should be discussed during the TL meetings.

Although the generic time line has been used by the facilitators to indicate the progress of their case, the temporality of the needed interactions with potential users was very different from one case to another and the organisation of these exchanges was decided by each facilitator or by each developer in an independent way. For instance, a high number of exchanges to identify the precise needs of covariates of practitioners and external academics have been implemented by e-mails each year of the project.

The development of a predictive tool about dengue and Aedes-related risk was structured around regular meetings with national agencies started in November 2022.

Some facilitator highlighted that this was an additional activity for them and that the time dedicated for research was a priority for their institutes. For example, the work to set up an EBS tool about AMR needed an important preliminary step of collective thinking on the objectives with experts which was not planned in terms of human resources.

The communication to inform externals and incite them to have exchanges with MOOD partners and to attend to MOOD events has been done by the WP6 through articles presenting the

case studies and feedback about the main events (General Assembly, Webinars, Summer schools, Christmas events) disseminated by the website, the newsletter, specific mailing and social medias). The main tools concerned by the co-conception process have been integrated in three generic modules (covariates, visualization/ EBS and risk maps). A high number of scientific outputs contributed to these modules (following the planned workflow between WPs) and other tools with a lower visibility (or a final TRL inferior to 9) have been discussed during the case studies.

2.2 Topics addressed during the exchanges with practitioners

Concerning the covariates, the process of interactions was complex since the interactions were conducted by the case facilitators, the modelers, the partner responsible of the covariates' module and the researcher in charge of providing the covariates sets. An initial list of covariates was defined by WP2, acquired and processed by WP3. The lead-expert of this task started exchanges with academics to identify new covariates on precise models (since the beginning of the project), while the partners were transmitting their requests of covariates needed for their modeling inputs in relation with corresponding to the user needs expressed. The covariates set was modified following requests of EI practitioners during GA or independent exchanges. These exchanges allowed to identify the most useful drivers and the expected format. For instance, a list of species of hosts and vectors was identified during the testing sessions of the GA 2023. The needs of covariates expressed in other projects (like E4Warning Project) were also taken into account to complete the list, but also the collaborations with other projects allowed some covariates to be developed that MOOD resources alone could not provide.

Padi-web was already existing before the start of MOOD and the improvement of the tool has been based on "Use Cases": specific interactions with each practitioner to define the key words in relation with the precise objectives of surveillance, and to test of the new algorithm by comparison of the outputs with owned health data. Ergonomics was also discussed during all these exchanges ("how are managed the doublons", "how to centralise the useful information"). The practices were also discussed in term of added-value of Padi-Web and complementarity with other aggregators. About AMR, the approach was different since the objectives had to be reviewed and a hackathon was organised to explore the feasibility of the surveillance. The new functionalities and ergonomics of Padi-Web have been presented discussed collectively during the GAs.

The concepts of the tools were in particular co-designed with the practitioners for HPAI and Dengue to fully address the surveillance objectives by model: a validation of the precise surveillance objectives with the corresponding set of solutions was made with the practitioners.

The concept of EDE was decided internally, partially on the request of partners (Covid-19) and in relation to technical constraints (resolution NUTS 3) but the sources of data were discussed with practitioners as well the capacity to use confidential data (expectation identified in the D1.1). An external researcher specialist of leptospirosis expressed the need to centralize, and visualize the animal cases at NUTS3 for France. The session of testing (GA 2023) allowed to identify the critical point of the installation of the EDE software on personal computers.

The scientific validation of the models used for the risk maps was implemented first with disease experts and the expectations of the practitioners were gradually taken into account (the drivers first, the uses lately and depending on the model). The interactions about the risk maps aimed to address the availability of health data and their legal management, the epidemiology of each model according to the geographical areas, the capacity to update the data. The discussions about ergonomics and the changes of practices at the scale of the routine (how these maps and datasets will be used) must be completed in 2024 through enquiries after autonomous testing of the risk maps module or during sessions of testing.

As a conclusion, the scientific validity was the core topic of the exchanges. The concepts of the tools have not been co-designed systematically at an early stage with EI practitioners but all dimensions were discussed during the testing sessions (GA of 2023) for the tested modules thanks to open questions on the usefulness, the difficulties met and the expected improvements. The exchanges with potential users were heterogenous according to the tool and the module. Complementary exchanges about associated needs in terms of technical improvements, information and training remains to be implemented concerning the tools that have not been tested and also at the scale of the platform. An assessment of the use of the platform and related perceptions, in organized sessions and/or through autonomous testing, are necessary to complete the identification of the wanted innovations and ease the change of practices.

3.1 Identification of the innovations

An innovation corresponds to a new practice, a new use of a tool, the use of a new tool in a social group (here among the professionals in charge of detecting and monitoring EID in Europe). Multi-dimensional changes (organizational, legal, technical, new knowledge etc) are needed to reach a new practice at the collective scale and multiple changes will also occur as a consequence.

Thus, the identification of the innovations should correspond to identify the outcomes linked to the tools and services produced (after the effective change) but in an ex ante approach, we aim to identify the specifications of the new tools and services (the inventions) and how they will be used (for what purpose, leading to other changes).

A step-wise identification

At the time of release of the D1.1 (report on the user needs assessment) in early 2021, the coordination asked the WP leaders to write how they will revise their activities to take into account the problems to solve and objectives of the practitioners, and their general expectations. The needs i.e., the expected innovations, were not fully identified in terms of final tools and their precise uses.

The monitoring team (task 6.4) extracted from the proposal the expected outputs following the revision and started to identify the expected outcomes as a proxy of the innovations, thanks to the coordination, the sociologists and the WP leaders. This work shows that in 2021, the view on the final tools was not clear for many researchers in relation with a lack of knowledge of what will be produced by the other researchers from other tasks and in relation with the difficulty to assess the feasibility to produce a final prototype (ability to reach the last TRL).

A controversy appeared about the way to interact with EI practitioners to order to in-depth discuss their needs and the specifications of the tools, some developers preferred to speak about the generic modules, other preferred to work by model diseases. A pol during the GA 2021 validated the added value of the case studies that started in Q3 2021. In parallel, the developers of generic modules would gather the related needs identified in the framework of the case studies and along specific consultations regarding their module (in particular for the covariates modules and visualization). The generic access and ergonomics of the module concerning the risk maps must be discussed with EI practitioners in 2024.

Perimeter of the identified innovations

Three “modules” (Fig. 6) are the heart of the identified innovations and the coverage of disease models by module is depicted in Figure 7.

Fig. 6: The 3 modules gather different tools by concept and common functionalities

	HPAI	TBE	COVID-19	WNV	AMR	TU-LEPT	CHI-DEN-ZI
	Maria F. Vincenti G. maria.fernanda.vincenti.gonzalez@ulb.be	Timothee Dub timothee.dub@thl.fi	Chiara Poletto chiara.poletto@inserm.fr	Annapaola Rizzoli annapaola.rizzoli@fmach.it	Esther van Kleef evankleef@itg.be	Elena Arsevska elena.arsevska@cirad.fr	Renaud Lancelot renaud.lancelot@cirad.fr
1.	✓	✓	TO BE CONFIRMED	✓	TO BE CONFIRMED	✓	✓
2.	✓	✓	✓	✓	✓	✓	✓
3.	✓	✓	TO BE CONFIRMED	✓	✓	TO BE CONFIRMED	TO BE CONFIRMED

Fig. 7: Coverage of disease models by module

<u>Purpose of the 1st module:</u> access to covariates for climate, environment, hosts, vectors in Europe

The “Data & covariates access” module will be a one-stop “shop” for the visualisation and download of relevant standardised covariates used for modelling and risk assessment of infectious diseases.

<u>The feedback on the Data & Covariates Access Module draws the probable future uses (part “usefulness”) if the expectations regarding the ergonomic[2]s (“complexity”) and functionalities will be taken into account</u>

[2] compatibility between people and their work, both physically (study of work postures) and cognitively (study of mental processes), as well as organizationally (optimization of processes and organizations).

Out of 23 respondents, 65% found the module useful for visualisation, exploration, understanding of disease risk by easily accessing pre-processed spatio-temporal data and saving time for epidemiological analysis, time series analysis, modelling.

Some respondents (39%) encountered difficulties with the tool. Some were due to a lack of metadata, and the impossibility to display some rasters (previously uploaded) due to the reduced visibility when using a large geographical extent.

Half of respondents expressed the need for additional functionalities that would be useful for their work: other relevant environmental and vector/host species data, buffering around points, possibility to measure distance between points, improved metadata, different resolution settings and larger geographic coverage.

Purpose of the 2nd module EDE part: visualization

Epid-Data-Explorer (EDE) allows users to perform cross-regional and cross-temporal analyses of epidemiological data, as well as covariate data (e.g. weather data), through the MOOD platform or on a local server (on a personal computer, possibly with personal data).

The platform offers a range of capabilities such as: to view data at different levels of temporal resolution, zoom in on specific regions for closer inspection, compare the behaviour of a particular region with the entire dataset, download selected data, and compare two indicators from different datasets on the same interface.

The feedback from the participants on Epid-Data Explorer (EDE) draws the probable future uses

Out of 28 respondents, half of them found the EDE tool useful for exploratory analysis of drivers of trends / risks and comparison between countries.

However, most users (75%) encountered difficulties with the tool, mainly linked to installation of the standalone version and integration of their own data.

35% (n=10) of participants expressed the need for additional functionalities, such as: adapting choices of colour scales, additional data formats, raster (covariates for instance) with the outbreaks locations (latitude/longitude), more data sources and dot or spot map presentation.

Purpose of the 2nd module Padi-Web part: Media monitoring

PADI-web automatically collects news articles from Google News with custom queries, classifies them and extracts epidemiological information (diseases, dates, symptoms, hosts and locations).

The feedback from participants on PADI-web draws the probable future uses

Out of 28 respondents, 64% found the PADI-web tool useful for screening media and extracting information with tailored settings, for conducting a quick literature search for research, surveillance, early warning and preparedness activities.

Some participants (36%) encountered some difficulties while testing the tool. They suggested improvement of visual analytics, better and/or easier classifications and precisions in terms of outputs.

32% (n=9) of participants expressed the need for additional functionalities such as a more interactive interface, add contextual information to each of the signals/events detected, the possibility to group and/or select several signals into one event, provide the option to read the text from the news item in another window, and clarify names of PADI-web functions and some human-machine interface presentations.

Purpose of the 3rd Module: MOOD platform Disease Specific Module: Disease Risk Mapping

The Disease Risk Mapping Module provides risk maps and other modelled outputs, aiming at highlighting areas suitable for the occurrence of (mainly) specific zoonoses in animals and humans, to support improved disease detection, monitoring and surveillance.

Risk mapping of TBE and WNV: **several tools for several EI and risk assessment purposes**

For TBE, MOOD researchers presented annual **static maps** showing the probability of occurrence of human TBE cases at NUTS3 and municipal level, as well as **maps highlighting the appearance and disappearance of new risk areas** with respect to the previous year. These maps will be available on the MOOD platform.

They also presented research work on TBE drivers (literature review and dashboard) and investigation of ecological drivers of TBEV at the Palearctic scale using phylogeographic and niche modelling approaches that will lead to **static maps of sequences until 2022, with code made available to end users.**

Regarding ticks and other tick-borne pathogens, the MOOD team presented activities that are at different stages: a proof of concept of a tool that would recognize tick species from photographs taken by citizens, research work on **drivers of pathogen prevalence** that will lead to **guidelines** for end users, as well as ongoing work on seasonality indicator in order to produce **suitability masks** to be made available to end users of the covariate module.

As far as WNV is concerned, MOOD researchers presented published work on the contribution of climate change to its emergence in Europe and on the quantification of WNV force of human infection that will remain a scientific contribution.

<u>Feedback from the participants concerning TBE and WNV risk mapping</u>

Participants asked questions on the data used for modelling and the climatic variables that were considered as drivers. They also had questions on risk thresholds in modelling, whether a model could be made available for PH agencies to identify new locations at risk, as well as on potential functionalities of participatory apps i.e., get information on users participating to data collection, the efficiency of identification (including how to differ stages) as well as the possibility for users to report tick bites on animals.

Risk mapping of Dengue: predictive risk mapping

The web interface (R-Shiny application) aims to support decision-making for surveillance and control of Dengue, Chikungunya and Zika in Europe through a predictive mapping of *Aedes* vector density.

<u>Feedback from participants concerning the *Aedes albopictus* risk app</u>

The participants have tested the tool during the session. They recommended to improve the ergonomics of the interface. In terms of development, the model's parameters and functionalities were discussed. Users expressed the need to take into account different vector control strategies, the possibility of using their own datasets and the need to take into account socio-economic parameters in order to weight exposure.

The use and relevance of the model in various epidemic scenarios (international sport events in particular) was also discussed. The date of availability of the tool was also a concern.

Risk mapping of HPAI: several tools for several EI and risk assessment purposes

A list of covariates has been extracted from **literature search** for Influenza A, including environment, animals, and humans related covariates. There are different endpoints considered (outbreaks, % of positives, persistence in the matrices, infection rates in %), requesting a standardisation.

A wide range of covariates layers related to HPAI, including climatic, environmental and bird distribution will be available.

An algorithm will be available for an **unsupervised EBS** using an EpiDCA model. It has been applied to Avian Influenza in South East Asia region but it allows a generic approach (applicable to different diseases and environmental contexts). The evaluation framework comparing **PADI-web** (automated system), ProMED (moderated system) and Empres-i (ground-truth) on Avian Influenza animal cases from 2019 to 2021 showed that ProMED covers more countries, while PADI-web is timelier (Although ProMED better captures periodic events). Both systems rely mostly on different sources but PADI-web relies on more timely important news outlets.

A database of **standardised records from EMPRES-i and GenBank** will be available on the MOOD platform.

Static maps, analytical framework (commented codes), and manuscripts will be based on (1) mapping conversions of HPAI (mutations leading to LPAI to HPAI), (2) Risk mapping / Clustering of the probability of the disease occurrence among wild birds based on climatic data and vegetation indexes (ecology of migratory birds) at the MOOD extent, and (3) Risk mapping / Clustering of the probability of the disease occurrence among poultry birds based on proxys for poultry intensification, human and poultry density, among others. Several modelling approaches were used including GLM (Generalised linear models), INLA, BRT (boosted regression trees), etc.

<u>Feedback from participants concerning the HPAI tools</u>

Participants raised questions on three themes: (1) the validity and robustness of the outputs, their added-value and type of use in Padi-Web, (2) the development of an algorithm that could be used to update the list of covariates, their validation, and separation for influenza A and HPAI, (3) on the possible use of additional bird layers and on the ground source for HPAI modelling.

<u>Insights about the other case studies (not tested during the GA 2023)</u>

Leptospirosis case study

A survey about the epidemiological roles of the different populations of dogs has been implemented in La Réunion Island. The results will help to adapt the enquiry questionnaire of the local health authorities at destination of the human cases and will improve the epidemiological surveys as well as the recommendations to the population.

The EDE tool has been adapted to allow the visualization of confidential data, as requested by users for the visualization of animal cases of leptospirosis in France at the scale of department (NUTS3). This visualization can be done by any user having their datasets at the right format.

Covid-19 case study

A retrospective analysis of the quantitative modeling has been conducted by MOOD partners on the COVID-19 pandemic to reflect on the data needs, modeling tools used, and interaction with public health authorities. The analysis was based on the standardized data collected through a survey filled out by MOOD partners.

This study will improve the preparedness for the next pandemics by increasing the capacities of the modelers and better target the data collection.

3.2 Lessons learned on the process (aiming at co-creation)

Task 6.4 group conducted specific interviews with project partners on co-creation process applied in MOOD. Based on 10 online interviews of Key Informants (4 women, 6 men, from 6 different countries) involved since the beginning of the MOOD project (either during the proposal writing or just after), we explored challenges which could happen when developing co-creation process and possible solutions.

- We observed that the co-creation process was implemented in a very heterogenous way according to the tool and the development was delayed.
- The scientific/technical validation replaced quite often the process to check if the change of practices will be fully addressed.
- MOOD produced technical solutions on some priority expectations but other user needs were not addressed by MOOD or not translated into technical solutions: due to confidentiality issues (text mining tool of protected data flows), those linked to the modification of existing/in-home tools, those requiring a long process of anticipation and collective thinking (ex: review of EBS objectives on AMR).

We examined the levels at which responsibilities and involvement could be attributed during the co-creation process, namely, the organizational level and the operational level. Organizational level is composed of actors in charge of defining the terms of the project, writing the proposal, and managing the project. In our case, organizational level is composed of the coordination team, case study facilitators, managers and principal investigators. Operational level is composed of end-users (both from Public Health or Animal health institutes) and academics (developers, modelers, etc.). We refer to all the actors who collaborate within the co-creation process, such as “academic researchers (who may also assume the role of facilitating the process) and a combination of end-users and relevant stakeholders (dependent on the population group)” as “co-creators” (Leask al., 2019).

In the table below are presented the main results from our study, regarding the elements that were identified by Key Informants as important for an optimal co-creation process. These elements are categorized by levels (organizational versus operational) and thematic categories.

Table 1. Categories of elements to take into account for an optimal co-creation process

	Organizational level	Operational level
A/ Project organization	• Strengthen the social scientist / multidisciplinary team with previous experience • Common goals and understanding of co-creation process	• Shared and consensus-driven understanding of the project's modalities • Willingness to be part of the project under its conditions
B/ Scientific goals	• Offering a scientific interest	• Finding a scientific interest and feeling of accomplishment by being involved in co-creation
C/ Communication	• Clearly define regarding the level of collaboration • Mapping of actors • Communication tools	• Share languages (terminology...)
D/ Involvement	• Adjusting working groups / Optimal team size • Setting up a community of involved co-creators, from the beginning	• Know partners' competencies and way of working • Active collaboration

Co-creation is a complex process which involve a collective agreement on both organizational and operational levels and which requires professional skills as well as personal ones.

- The partners had different perceptions of the added-value and the needed modalities of a co-creation process. The concern on how to reach the full technical requirements expected by the developers from the first multi-dimensional user needs was underlined during internal meetings.
- An agreement on the objectives of the co-creation and its methods should have been reached during a face-to-face workshop at the start of the project, in order to clarify everyone's roles in particular. A main constraint was the absence of a face-to-face kick off meeting and a lack of communication in this large consortium whose workflow has been reorganized in relation with the Covid-19 crisis, preventing all the face-to-face meetings and mobilizing many researchers to address the scientific questions about Covid-19.
- Beyond this circumstantial stake, the process of the "learning loops" brought these lessons learnt that are useful for any project having the ambition of a co-creation process.

Conclusion

The MOOD project has chosen to implement a co-creation approach in order to adapt the tools and services to the users' need and their work conditions. Following a participatory users'needs assessment, the co-creation process has been organized around the hybridation of the planned activities of the "learning loops" with a strategy based on study cases.

Although the co-creation process was implemented in a very heterogenous way according to the tool, many dimensions of the expected innovations have been discussed with the EI practitioners and their identification have been gradually implemented. The exchanges with the EI practitioners aimed to articulate a scientific validity of the tools that will be produced and an effectiveness of their use in a given professional environment. After the integration of the tools in the MOOD platform and its release, an analysis of the perceptions of the uses of this platform is needed to complete the overview of the expected changes of EI practices.

Beyond the circumstantial constraint of the Covid crisis, the process of the "learning loops" brought some lessons learnt that are useful for any project having the ambition of a co-creation process.

References

Darré, JP (2006). La recherche co-active de solutions entre agents de développement et agriculteurs. Editions Gret, Cnearc, Gerdal.

Leask, C.F., Sandlund, M., Skelton, D.A. *et al.* (2019). Framework, principles and recommendations for utilising participatory methodologies in the co-creation and evaluation of public health interventions. *Res Involv Engagem* **5**, 2. https://doi.org/10.1186/s40900-018-0136-9

Vargas, C., Whelan, J., Brimblecombe, J., & Allender, S. (2022). Co-creation, co-design, co-production for public health: a perspective on definition and distinctions. Public Health Research & Practice, 32(2).

Voorberg, W. H., Bekkers, V. J., & Tummers, L. G. (2015). A systematic review of co-creation and co-production: Embarking on the social innovation journey. Public management review, 17(9), 1333-1357.