MOOD

Monitoring Outbreak events or Disease surveillance in a data science context

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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
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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, IRSTEA, OPENGEOHUB, UOXF, ISS, THL, GERDAL, IPHS, ISCIII, ANSES, INRA, ISID

Executive Summary

The three objectives of the monitoring and evaluation analysis are: (1) to monitor and characterize the innovation process of the MOOD project, (2) to understand the motivations, opportunities and barriers to the co-creation process, and (3) to implement an ex-ante assessment of the MOOD outcomes impacting practices, interactions and knowledge at least at the level of end-users and set basis to continue this assessment. The results will be used as an input for the innovation pathway of the project (task 7.5), with identification of the main outcomes, indicators of access to outputs, quality of collaboration, practices and perceptions, periodically reviewed to track and refine the probable impact of MOOD. The lessons learnt will allow to draw some recommendations for co-creation processes in the area of public health and to continue the monitoring of the outcomes for this project.

Keywords

Output, outcome, co-creation process, impact, tools, innovation

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Contents

Introduction

MOOD aims to develop innovative tools and services to monitor current and future infectious disease threats in the context of global, environmental, and climatic change. Through big data and disease modeling innovations and other tools or services allowing a better use of the available data (as access to processed and standardized covariates and visualization), the MOOD project is designed to address the challenges of cross-sectoral data sharing and valorization in a One Health framework based on multi-disciplinary collaborations for animal, human, and environmental health. Co-creation[1] of tools and services with human and veterinary public-health agencies, responsible for designing and implementing strategies to mitigate the identified risks, is at the core of MOOD innovation. MOOD primary objective is to increase the capacities of stakeholders at public and veterinary health agencies (referred hereafter as end-users) to improve their epidemiological data management practices, particularly digital and related to the use of big data, to better detect and manage the risk associated with emerging infectious diseases. Accordingly, the major outputs of the MOOD project are new digital tools and services such as maps, models, collection tools that format digital data in a way that can be used 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.

Since the writing of the proposal, the MOOD project have underscored the critical need for a comprehensive impact assessment strategy. Implementing an in itinere monitoring of the impact allows the project to proactively evaluate the potential outcomes and impacts before full-scale deployment and to adapt the innovation process in order to reach the expected impact. This approach enables to identify potential challenges, gaps, or areas of improvement in the project's design and implementation, fostering a more adaptive and responsive framework. The initial choice of co-conception, involving collaborative efforts with human and veterinary public-health agencies, sets the foundation for a holistic impact assessment.

The co-creation process ensures that the tools and services developed align with the practical needs and operational realities faced by these agencies. This participatory approach not only enhances the relevance and effectiveness of digital solutions but also facilitates a more accurate assessment of their impact in real-world scenarios. The expected assessment of the impact serves as a crucial feedback loop, allowing the MOOD project to measure the actual capacities of its outputs on improving epidemic intelligence practices in terms of usefulness, ergonomics and sustainability. By incorporating feedback from end-users, the project can iteratively refine its tools and services to address emerging challenges, ensuring sustained and meaningful contributions to the early detection, monitoring, and assessment of risks associated with emerging infectious diseases.

[1] "Co-creation" is an overarching construct, which is defined as the active involvement of stakeholders, 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).

1 Monitoring and assessing the co-conception process, scientist-user interaction

1.1 Identification and characterization of MOOD tools and services

1.1.1 Method used

MOOD tools and services that are planned to be produced within MOOD were identified from the proposal and by contacting subtask leaders and partners for reviewing and updating the work program (e.g., a new tool or activity proposed) from M13 to M47 (January 2021 to November 2023). A range of information, such as the objective of the tool or service, disease model and method used, expected output, potential outcome, and impact of each tool and service, was collected. Periodic inventory of MOOD tools and services (existing and new) is continuing. The assessment of the readiness level (TRL)[2] and uptake[3] was conducted through interviews of partners/developers during M26-M33 and M45-M47 of the project.

The inventory of MOOD tools and services (including new tools and further developments of pre-existing tools) is also updated by the partners in charge of the MOOD platform. Regular monitoring of production, TRL and uptake of MOOD outputs is conducted throughout the project through a specific annual KPI**: KPI.13**: Production and readiness level of MOOD tools for the detection/prediction of emerging diseases and also **KPI.19**: Toolkit & Tutorial/cookbook: number of tools and tutorials.

1.1.2 Presentation of the main modules and tools in 2023

The delay in finalizing the tools and the ongoing uncertainties led us to focus our monitoring efforts on a specific set of tools and modules considered crucial for the platform, which we are presented below.

Module 1 Data & covariates access

<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.

[2] **TRLs** are a set of management metrics that enable the assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of technology—all in the context of a specific system, application and operational environment.

[3] **Uptake of a specific tool:** The tool or service has been uptaken when the end-user has included the tool or service in its routine (ideal situation).

Module 2 Epi-Data-Explorer (EDE)

Purpose of the 2nd module EDE part: visualization

Epi-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 viewing data at different levels of temporal resolution, zooming in on specific regions for closer inspection, comparing the behaviour of a particular region with the entire dataset, downloading selected data, and comparing two indicators from different datasets on the same interface.

Module 3 PADI-web

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).

Module 4 Disease specific risk maps

Not implemented in 2023, but with intention in 2024.

1.2 Mapping the stakeholders

1.2.1 Method

Participation of stakeholders was characterized longitudinally. We monitored the “exchange process” between MOOD partners and end-users regarding services and tools development using the following methods:

- **Interviews** (preliminary interviews, socio-interviews, interviews on impact assessment and involvement in the MOOD project) and questionnaires sent by email or disseminated during an event.
- Inventory of the participation of end-users to **workshops and events** (such as General Assembly and Christmas event) organised by MOOD coordination team and partners.
- **Email exchanges** (between some partners and end-users regarding a specific tool) on specific topics and case studies.
- **One-to-one or group meetings** on specific topics and case studies.

We also assessed the level of integration of end-users in the co-creation process by analyzing the roles of the different actors during the successive stages of the process by case study and across time.

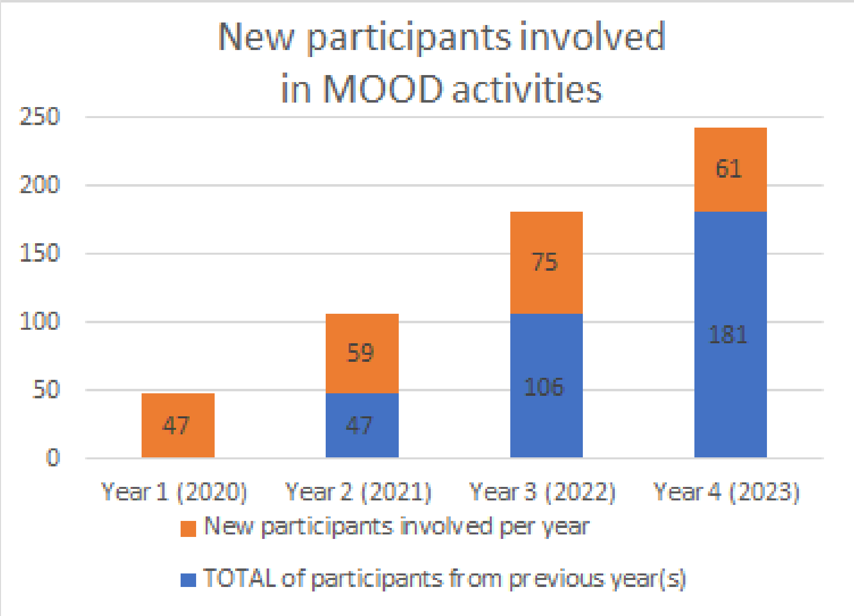
We consider that some one-to-one exchanges or group activities regarding MOOD tools development may not have been reported. The number of actual participation is not exhaustive and may be higher than the one we present.

1.2.2 Results

By December 2023, we identified 242 unique participants of 120 PH/AH institutions (from 48 countries and 8 international agencies) involved in one or several activities as potential end-users for MOOD tools and services. Among them, 33 participants (of 14 agencies from Finland, France, Italy, Serbia, Spain and ECDC) were consulted on their needs at the beginning of the project though interviews and workshops (tasks 1.1.2 and 1.1.3).

Each year, more participants joined the MOOD activities: from 47 participants involved in Year 1 (2020), we reached 59 new participants[4] in Year 2 (2021), 75 new participants in Year 3 (2022) and 61 new participants in Year 4 (2023) (see Figure 1). The number of new participants reached over the four years of the project has been multiplied by 5,1 from Year 1 to Year 4.

Figure 1. Number of new and total participants involved in MOOD activities over the years



Overall, an average of 85 unique participants[5] were involved each year in the recorded activities. The breakdown of participants per activity is shown in Table 1:

[4] **New participants per year** refers to the number of new people who joined MOOD activities during the year, and who were not involved in the previous year(s).

[5] **Unique participant each year** refers to the number of people who participated, for one year, to one or more activities.

Table 1. Number of unique participants per activity and per year

	Year 1 (2020)	Year 2 (2021)	Year 3 (2022)	Year 4 (2023)
Interviews, questionnaire	33	50	42	62
Workshops and events	16	34	66	55
E-mails exchanges	11	14	12	11
One-to-one or group meetings	0	16	36	43
TOTAL of unique participants per year	**47**	**82**	**116**	**95**

We have seen an important increase in the number of participations over the years, as shown in Table 2.

Table 2. Number of participations per type of exchanges and per year and evolution (in %)

	Year 1 (2020)	Year 2 (2021)	Year 3 (2022)	Year 4 (2023)
Interviews, questionnaire	43	78	47	141
Workshops and events	26	34	79	56
E-mails exchanges	11	16	42	21
One-to-one or group meetings	0	16	41	57
TOTAL of participations	**80**	**144**	**209**	**275**
Evolution of participations (in %) compared to previous year	N/A	80	45,1	31,6
Evolution of participations (in %) compared to Year 1	N/A	80	161,3	243,8

Over the 4 years of the project and in all MOOD activities, we recorded a total of 708 participations.

On average, the number of events per participant was 1.7 in Year 1, 2.4 in Year 2, 2.8 in Year 3 and 4.0 in Year 4.

Using a qualitative approach, we also conducted 16 interviews with partners and three with potential end-users. Table 3 summarises the current state of the art regarding the uptake of the MOOD tools by PH/AH agencies. From all the interviewees (n=15), five respondents are involved in the data and covariate access module, three in the general data access module, six in the disease-specific risk map module, and one in communication.

Among the 15 interviewed partners, six have established contact with practitioners/ potential users. Out of these six, three partners involve EI practitioners in the tool development process beyond the organised meetings. The three tools concerned by the co-conception between partners and the interviewed end-users include a platform for automated extraction of disease information from the web (PADI-web), a web interface (Epi-Data-Explorer (EDE)) for event-based surveillance (EBS) and indicator-based surveillance (IBS) data, and a dashboard for visualisation of disease-specific covariates extracted from the literature (Tick-borne encephalitis (TBE) covariate dashboard) and the covariates module.

Among the above-mentioned tools, PADI-web is used by the French animal health epidemiological surveillance platform (ESA platform) in their regular activities to monitor animal health risks in Europe and beyond that threaten animal populations in France. For the TBE covariate dashboard, the Finnish Institute for Health and Welfare (THL) and the Italian public health institution (ISS) are identified as potential end-users and participating in the development process. The Epi-Data-Explorer is an interface to explore EBS data (from PADI-Web) and IBS data. The ESA platform, VetAgro Sup, and the Swiss Institute of Bioinformatics (SIB) tested the prototype; the European Centre for Disease Prevention and Control (ECDC) and the World Organization for Animal Health (WOAH) disclosed interest in using this tool.

The covariate access concerned the data in open source that people can download freely. There were more than 75,000 downloads by the time of the interview (29/04/2022). The tool does not enable to track the country and agency of those users. Around 1,000 users download the same data every week. This monitoring was done through independent access directly to the downloading platform. Besides, ECDC, Edmund Mach Foundation, National Institute of Health and Medical Research (INSERM), University of Oxford, and Free University of Brussels (ULB) have been provided with specific data format at their request.

Table 3. Number of European PH/AH agencies who have used the MOOD tools, by October 2022

Number of PH/AH agencies and research institutions who have established contact with MOOD partners (developers) beyond the organized meetings. • *French animal health epidemiological surveillance platform - ESA platform (for two tools)* • *French veterinary school (Vet Agro Sup)* • *Swiss Institute of Bioinformatics (SIB)* • *Finnish Institute for Health and Welfare (THL)* • *Italian public health institution (ISS)* • *European Centre for Disease Prevention and Control (ECDC) (for two tools)* • *World Organization for Animal Health (WOAH)* • *Edmund Mach Foundation* • *National Institute of Health and Medical Research (INSERM)* • *University of Oxford* • *Free University of Brussels (ULB)*	11
The number of PH/AH agencies and research institutions involved in the tool development process beyond the organised meetings. • *French animal health epidemiological surveillance platform - ESA platform (for two tools)* • *French veterinary school (Vet Agro Sup)* • *Swiss Institute of Bioinformatics (SIB)* • *Finnish Institute for Health and Welfare (THL)* • *Italian public health institution (ISS)*	5
Number of PH/AH agencies who have included at least one MOOD tool in their regular processes to perform detection, assessment, and monitoring activities of disease threats. • *French animal health epidemiological surveillance platform - ESA platform (for PADI-Web)*	1

1.3 Analysis of the collaboration process between partners and end-users during the development of the tools and services

1.3.1 Method

We assessed the collaboration and co-creation process, as well as new knowledge and epidemic intelligence practices linked to MOOD tools and services, by conducting interviews with developers and monitoring tool development and advancement throughout the project timeline. We also quantified the number of public health (PH) and animal health (AH) agencies at national and international levels that implemented at least one MOOD tool in their regular processes to perform detection, assessment, and monitoring activities of disease threats. Including the tools may result in official new/adapted guidelines and workflows.

We use the term "co-creation" to define an overarching construct, which is defined as the active involvement of stakeholders, 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).

From March to November 2022 (M27 to M35), we conducted 14 qualitative interviews with partners and three with potential end-users. These three potential end-users have been closely involved in the co-creation process with the MOOD partners of the following tools: a platform for automated extraction of disease information from the web (PADI-web), a web interface (Epi data explorer) for event-based surveillance (EBS) and indicator-based surveillance (IBS data), and a dashboard for visualisation of disease-specific covariates extracted from the literature (Tick-borne encephalitis (TBE) covariate dashboard).

From March to May 2023 (M39 to M41), we also conducted ten interviews of Key Informants (4 women and 6 men from 6 different countries) who are MOOD partners involved since the beginning of the MOOD project (either during proposal writing or just after), to explore challenges which could happen when developing co-creation process and possible solutions.

1.3.2 Results

The number of MOOD events per participant each year has increased. However, participants were not involved in the same frequency. Over the 4 years, among the 242 total participants, we noted that:

- 220 unique participants (91%) participated in **1 to 5 events**.
- 15 unique participants (6%) participated in **6 to 10 events**.
- 7 unique participants (3%) participated in **more than ten events (up to 14)**.

Semi-structured interviews, observations during meetings and follow-ups of email exchanges have shown, so far, different kinds of potential end-user participation, which can be characterized as low, medium, or high.

Low participation can be identified mostly as "attending" events and rarely responding to solicitation:

- No or rare participation in meetings and exchanges
- No or rare email exchange for the process of co-creation
- No or rare response to solicitation for tool development

It can be summarised as "Attending", as a passive way of participating.

Medium participation can be identified as moderate participation to events and response to solicitation to give some inputs without initiating communication (i.e. participation to events and solicitation organized by others, such as MOOD):

- Moderate participations in meetings and exchanges
- Moderate email exchange for the process of co-creation
- Response to solicitation for the tool development

It can be summarized as “Responding”, as a moderately active way of participating.

Based on our data (interviews), the participation of 2 end-user’s interviewees can be characterized as medium participation.

High participation can be identified as actively asking for inputs and generating collaboration, producing specific responses and disseminating new tools in the personal network:

- Frequent participation in meetings and exchanges
- Frequent email exchanges for the process of co-creation
- Initiation of meetings
- Initiation of active communication (emails, calls, online meeting)
- Dissemination of information regarding tools and “recruitment” of new end-users in their own network

It can be summarized as “Initiating”, as a highly active way of participating.

Based on our data (interviews), the participation of 1 end-user interviewee can be characterized as high participation.

Our three interviewees have medium or high participation, but there is a recruitment bias as we selected potential end-users who are already well involved in the case studies. Most of the participants attended MOOD events (General Assembly, Christmas event) and had low participation. The developers work with a few potential users (PADI-web, EDE, dashboard for TBE) to identify precise technical requirements while strategic choices (data sources, sustainability of the tools) are discussed during these MOOD meetings.

Regarding collaboration, we recorded several types of exchanges involving end-users characterised in the following groups (Cf Table 2):

Interviews started in Year 1 with preliminary interviews and sociological interviews to gather users’ needs, followed in Year 2 by questionnaires on the state of the art and specific needs and interests in future MOOD outputs, such as Epi-Data-Explorer tool, text mining, modelling and tool access. In Year 3, we interviewed end-users in Réunion island and Mayotte. We also interviewed 3 end-users presenting a medium and high participation in MOOD tools development. Finally, in Year 3, we sent a questionnaire during MOOD remote Christmas event to renew the gathering of users’ needs after presenting the evolution of development. In Year 4, several questionnaires were sent during events such as Summer School and General Meeting Assembly in Helsinki, on participants’ EI activities, expectations and preference, and also on the satisfaction after tools testing sessions for Avia-Gis platform (Data and covariates access module), Epi-Data-Explorer and PADI-web.

Workshops and events consist mainly of MOOD events such as General Assembly meeting (with case-studies presentation), Christmas events and Summer Schools. These face-to-face events (from Year 3, after restrictions on gatherings were totally lifted) allowed partners and end-users to meet and exchange both on a formal and informal level and accelerated exchanges and collaboration between stakeholders.

Email exchanges took place between some partners and regular end-users specialized in their specific topic, such as covariates and PADI-web.

Regarding involvement of end-users, we notice that more **one-to-one and group meetings** occurred in Year 2, when knowledge between partners and end-users was more developed, after events and meetings of Year 1. We remind that Year 1 (2020) was marked by a specific context, including the Covid pandemic and lockdown. Therefore, several face-to-face events were either cancelled or adapted remotely. In Year 2, one-to-one and groups meetings occurred with specific topics and case-studies developed in MOOD such as HPAI and AMR. In Year 3, in addition to the continuity of meetings on AMR, we noticed several meetings on WNV and TBE case-study and on PADI-web development, as well as meetings with new partners in Indian ocean and the Caribbeans. In Year 4, these group meetings concerned Dengue-Chikungunya case-study, TBE and partners in Indian ocean.

Interviews with Key Informants showed that the co-creation process was implemented in a very heterogeneous way according to the tool, and the development was delayed. The scientific/technical validation replaced quite often the process to check whether 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 4 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 4. Categories of elements to take into account for an optimal co-creation process, based on key informant interviews

	Organizational level	Operational level
Project organisation	- Strengthen the social scientist / multidisciplinary team with previous experience - Common goals and understanding of the co-creation process	- Shared and consensus-driven understanding of the project's modalities - Willingness to be part of the project under its conditions
Scientific goals	- Offering a scientific interest	- Finding a scientific interest and feeling of accomplishment by being involved in co-creation
Communication	- Clearly define regarding the level of collaboration - Mapping of actors - Communication tools	- Share languages (terminology...)
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 involves 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, to clarify everyone's roles. A main constraint was the absence of a face-to-face kick-off meeting and a lack of communication regarding the co-creation principle in this large consortium because of the Covid-19 crisis.
- Beyond this circumstantial stake, analysing this process (the "learning loops"of MOOD project) brought these lessons learnt that are useful for any project having the ambition of a co-creation process.

2 Contribution to the identification of the outcomes and probable changes of practices

2.1 Method to monitor the outcomes

While our evaluation plan initially included a baseline assessment to review the performance of existing tools and user practices before implementing MOOD tools and services, and later on measuring real practice changes brought by MOOD innovation, the constraints of the project timeline prevented us from directly observing these changes.

Despite this constraint, we interviewed developers and end-users to gain insights into the needed improvements of existing tools or practices (seen as tools limitations by the developers), their plans to overcome the tools' limitations, and the expected outputs and added value of their new tools. Specifically, we inquired about the indicators developers aim to improve, such as simplicity, flexibility, data quality, acceptability, sensitivity, positive predictive value, representativeness, timeliness, stability, usefulness, and cost-effectiveness.

These interviews yielded valuable information for assessing the effectiveness of their tools in detecting infectious threats, even though direct observations of end-user practices were not feasible in 2023. However, they did a test during the GA 2023, and we have some partial results from the user's point of view. During the General Assembly Meeting in Helsinki (M42; June 2023), three tools were presented and then tested by participants. We conducted a questionnaire after the 3 tool testing sessions to capture "on the spot" end-users reactions after the test and exploration they just made of each tool.

Data collection methods included qualitative and semi-quantitative interviews. Specific tools for data collection, such as interview guides, have been designed to facilitate this process that contributed to a comprehensive understanding of the baseline scenario, laying the groundwork for the subsequent integration and assessment of MOOD tools and sustainable changes of practices that will contribute to enhancing the overall effectiveness of infectious threat detection and surveillance practices.

2.2 Results: Added value of the tools and perceptions at the stage of testing

Within the MOOD project, a diverse array of tools and services offer distinctive advantages, addressing critical aspects of infectious threat detection. The "**Platform for Automated Extraction of Disease Information from the Web – PADI-Web**" stands out for its ability to enhance Epidemic Intelligence (EI) timeliness and ergonomics by proactively detecting information in the press before traditional channels.

The feedback from the tool testing session participants on PADI-web shows the following users' experiences:

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 and 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, adding contextual information to each of the signals/events detected, the possibility to group and select several signals into one event, providing 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.

Meanwhile, the "TBE, WNV, Dengue and Chik Covariates Dashboard" provides a user-friendly interface, enabling easy access to literature in a consolidated location. Literature data collection and disease profiling by MOOD partners play a pivotal role by identifying the most important drivers (for all the MOOD models and ecological framework) and aggregating data from various searches, contributing to a more comprehensive analysis. This extends beyond classical epidemiological data, incorporating covariates from diverse searches and different drivers. The covariate data collection was adaptable across spatial scales, handling data at pixel or administrative levels. It ensures flexibility and standardisation by aggregating information based on specified parameters, such as one, five, or ten kilometres at the pixel level, and typically NUTS three or occasionally NUTS one at the administrative level.

The overarching **MOOD Platform** will be a centralized repository, seamlessly integrating diverse data sources for infectious threat detection and assessment. This innovative hub plays a pivotal role in creating a cohesive approach by consolidating information streams and facilitating a nuanced analysis of infectious diseases. The platform not only streamlines data accessibility but also tools and models that enhance overall efficiency and ergonomics (by the centralisation of the information and time-saving by having access to selected information or already processed covariates). In essence, the MOOD Platform stands as a cornerstone, fortifying the framework's capabilities in infectious threat monitoring. Serving as a centralised repository, the Resistance Bank streamlines passive surveillance on antibiotic resistance across low and middle-income countries.

The feedback on the MOOD platform Data & Covariates Access Module collected during the General Assembly testing session draws the probable future uses (part "usefulness") if the expectations regarding the ergonomics[6] ("complexity") and functionalities will be considered.

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

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

Half of the 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, the possibility to measure the distance between points, improved metadata, different resolution settings and more extensive geographic coverage.

In the realm of epidemiological modelling, phylogenomics and metagenomics and reconstructing epidemiological models introduced an innovative disease detection algorithm. This not only enhances the model's sensitivity but also improves timeliness and positive predictive value. The "**Epid Data Explorer**" offers a valuable feature with its double dashboard, facilitating efficient data comparison. The "SPREAD" tool is instrumental in producing statistical distributions of temporal-spatial phylogenies, introducing new opportunities for statistical phylogenetics. With the advent of MOOD, there has been a shift towards web visualization, ensuring accessibility and ease of use for researchers.

[6] 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).

The feedback from the GA participants on Epi-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 the installation of the standalone version and integration of their 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 outbreak locations (latitude/longitude), more data sources and dot or spot map presentation.

The implementation of Data Storage, Specification from Data Sources to Data Normalization, and Data Integration is a user-centric solution brought by MOOD, allowing researchers to specify parameters based on their requirements. This flexibility ensures data is processed in the desired format, promoting streamlined data processing and analysis. The geospatial Data Analysis and open source development embrace the ethos of open collaboration. By sharing tools as open source on Zenodo, it democratises access to valuable resources, transforming big data into reduced datasets. This strategy not only enhances accessibility for modellers but also contributes to a more inclusive and impactful landscape in health-related geospatial data analysis. Lastly, in response to critical global health challenges, the risk of importation of SARS-CoV-2 to Europe encompasses a digital contact tracing application and modelling for vaccination strategies. These studies are pivotal in guiding interventions, particularly when uncertainties abound.

In analysing the criteria and perceptions of EI practitioners regarding the necessary changes in their practices, we examined their discourse and responses from the online questionnaire. Their criteria concerned useful functionalities with technical requirements such as improved metadata, functionalities for measuring, useful layers of covariates, ergonomics for the centralisation and data integration, settings for a user-friendly interface, intuitiveness and easiness of installing the software. Researchers want to keep control of the data and analyses, and thus requested the ability to integrate their data without sharing them, to have better information about the tools' modalities of use and the sources of covariates, to have information about the tools' maintenance and update after the end of the project. These criteria and expectations go beyond the tools' limitations.

Limits of the existing tool(s) / practices addressed by MOOD innovation

The MOOD innovation effectively addresses several limitations in the existing landscape. The reliance on Google News data and limited language coverage is broadened by the new version of PADI-Web, which diversifies data sources and widens language inclusivity. This innovation ensures a more comprehensive and representative dataset for analysis. The spatial resolution and aggregation concerns are tackled through "Covariate Data Collection," allowing users to specify parameters based on their modelling requirements. This flexibility ensures a seamless integration of data at different spatial resolutions and time and a better ergonomics.

The time-consuming nature of searching for diverse and needed data across multiple platforms is streamlined by the "MOOD Platform," which consolidates various data sources into a single accessible repository. This addresses the challenge of navigating different platforms for relevant information and the struggle for integrating data with various formats. The absence of an online repository for point prevalence surveys on antimicrobial resistance (AMR) in animals, particularly in low and middle-income countries, is a unique limitation addressed by the "Resistance Bank." Serving as a focal point for passive surveillance on antibiotic resistance, it fills a critical gap in existing resources.

The limitation of most applications being restricted to mapping phylogenetic tip taxa to their geographical coordinates is overcome by the latest version of "SPREAD." This tool goes beyond by producing statistical distributions of temporal-spatial phylogenies, providing a more comprehensive understanding of phylogeographic histories.

False positive signals, often a concern in detection systems, are mitigated through the advanced anomaly detection algorithm. The algorithm ensures a higher sensitivity and positive predictive value, reducing the likelihood of false positives. Visualization challenges are addressed by tools like the "Epid Data Explorer," providing a double dashboard for efficient data comparison. This feature enhances the interpretability of complex data, addressing the limitation of a lack of proper visualization. In conclusion, the MOOD innovation demonstrates a concerted effort to address various limitations in the existing tools/practices for epidemic intelligence and disease surveillance, ensuring a more robust, flexible, and inclusive approach to infectious threat detection and assessment. Table 5 below summarizes the limitations of the existing tool(s) or practices that MOOD researchers took the initiative to address.

Table 5. Tool/Service Overview and Enhancements in MOOD Innovation

Name of the tool(s)/services	Limits of the existing tool(s) / practices	Improvements of existing tools/practices addressed by MOOD innovation	Performance indicator(s) for the MOOD innovation
Platform for Automated extraction of Disease Information from the web	False positive signals, luck of proper visualization, use only google news data, using very few languages Difficulties to manage high volumes of data and to extract easily the accurate information	Interactive visualization and analytics of the detected signals Allow extraction of events (selection of the needed information) and monitoring for a given country and disease. Expand language coverage	Sensitivity Timeliness Centralization/integration
TBE Covariates Dashboard	Absence of a centralizing tool	Extracting data manually take a long time	Simplicity Accessibility
Literature data collection and disease profiling	Absence of agreement on the best drivers	Identification of the best drivers in an OH approach	Simplicity, accessibility
Covariate data collection	Need a different spatial resolution or aggregation depending on the modeling work.	Producing already processed covariate data with spatial resolution or aggregation depending on the modeling work	Simplicity Accessibility Data quality Usability

Name of the tool(s)/services	Limits of the existing tool(s) / practices	Improvements of existing tools/practices addressed by MOOD innovation	Performance indicator(s) for the MOOD innovation
	Time consuming collection in scattered sources		
MOOD platform	Time consuming to go on different platforms to look for different and interesting data Difficult access to free tools Lack of methodological guidance	Create a common platform with a lot of functionalities, methodological guidance	Simplicity Accessibility Usability
Resistance bank	Lack of online repository for point prevalence surveys on antimicrobial resistance (AMR) in animals, with a focus on low and middle-income countries (not addressed by other similar works)	Filling the gap and refining a little bit the picture of the established surveillance initiative from governments and from the EU commission.	Accessibility
Phylogenomics and metagenomics and reconstructing epidemiological models			
Algorithm for anomaly detection	The current method is traditional models.	Deep learning models with better performance	Sensitivity Timeliness Positive predictive value
Epid Data Explorer	There is a lack of visualization tools for exploration of spatio-temporal data	Visualization of health data at NUTS3 with many settings and the possibility to integrate confidential data	Simplicity Usefulness
SPREAD	Most applications remain limited to mapping phylogenetic tip taxa to their geographical coordinates. Mapping phylogeographic histories of geo-referenced taxa requires a robust statistical estimate of the geographic locations at the ancestral nodes of the tree.	Proposed a suite of Bayesian inference approaches for the joint reconstruction of evolutionary and geographic history. Models that accommodate spatial diffusion in discrete and continuous space have been implemented in a flexible Bayesian statistical framework for hypothesis testing based on time-measured evolutionary histories.	Effectiveness, simplicity, usefulness

Name of the tool(s)/services	Limits of the existing tool(s) / practices	Improvements of existing tools/practices addressed by MOOD innovation	Performance indicator(s) for the MOOD innovation
Implementation of data storage, specification from the data sources to data normalization, data integration	Lack of centralizing data repository	Integration of data	Simplicity, Accessibility, Data quality, Usability
Risk of importation of SARS-Cov2 to Europe Digital contact tracing application. Modeling on possible vaccination strategies in particular, a reactive vaccination strategy.	Lack of free available tools for SARS-Cov2	-	Positive predictive value
Geospatial data analysis and open-source development	Need a different spatial resolution or aggregation over time.	-	Simplicity, Accessibility Data quality Usability
Risk estimate model			

MOOD platform will provide central access to data, methodological guidance and free tools, enabling the centralisation and data integration and improving EI activities ergonomics. Other tools are currently under development but were not assessed through this protocol. However, they might be presented and available at the end of the project.

2.3 Recommendations for further impact assessment

Next, outcomes assessment should be implemented at the platform's scale rather than tool by tool. It also can be conducted in different ways depending on the targeted users. The approach adopted closely depends on the relationship and prior knowledge between developers and end-users, as well as the type of previous collaboration between them.

For "privileged users" already in contact with the developers, establishing regular exchanges is envisaged to enhance the tool in real-time, in line with the users' ongoing utilisation. This assessment involves continuous communication and regular interviews.

However, for "unknown users" (the general public using the tool), developers can implement a questionnaire sent in the form of a pop-up window while users are still on the web page to gather their satisfaction levels regarding their recent experience. This assessment can be conducted on a one-time basis.

Additionally, a "feedback" button may be integrated into the platform page to facilitate communication and allow users to provide feedback whenever they wish.

Based on our experience, we suggest that impact assessment is a task that should take place before, during and especially after the development to be assessed: an ex-ante/in-itinere assessment has many limitations and should be completed by an ex-post assessment. This last part is especially important when assessing the change of practices, with concrete data from interviews and observations from the end-users who are actually testing or already using the tool(s). An impact assessment may not be complete without the third and last part of the assessment after the final development of the tool(s).

To optimise impact assessment, we finally suggest a clear timetable to be established at the start of the project and to be validated and observed by all stakeholders, particularly for planned developments.

3 Conclusion

In the monitoring of MOOD outcomes, we aimed to monitor and characterize the innovation process within the project, by focusing on the co-creation process of tools. With qualitative interviews of partners involved in the project, we sought to comprehend the motivations, opportunities and barriers associated with this co-creation process. We implemented an ex ante evaluation of the MOOD outcomes, focusing on their impact on practices, interactions, and knowledge at the end-user level. Achieving these objectives served as a foundation for the ongoing evaluation of the project, providing valuable insights into the innovation pathway. Periodic review of key results, access indicators, collaboration quality, practices, and perceptions guided the project's evolution and strengthened its potential impact. We had to adapt our initial methodology to address challenges encountered within the project, including delays in developing certain tools or collaborations. Lastly, the lessons learned from this analysis not only allowed us to formulate recommendations for co-creation processes in public health but also directed the ongoing monitoring of MOOD project outcomes for the upcoming year.