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JRC TECHNICAL REPORT

Integration of the Epidemic Intelligence from Open Sources (EIOS) system and the INFORM suite

Enhancing early warning with contextual data for informed decision making

Spagnolo, L., AbdelMalik, P., Doherty, B., Fabbri, M., Linge, J., Marin Ferrer, M., Moussas, C., Osato, F., Petrillo, M., Poljanšek, K., Schnitzler, J., Vernaccini, L.

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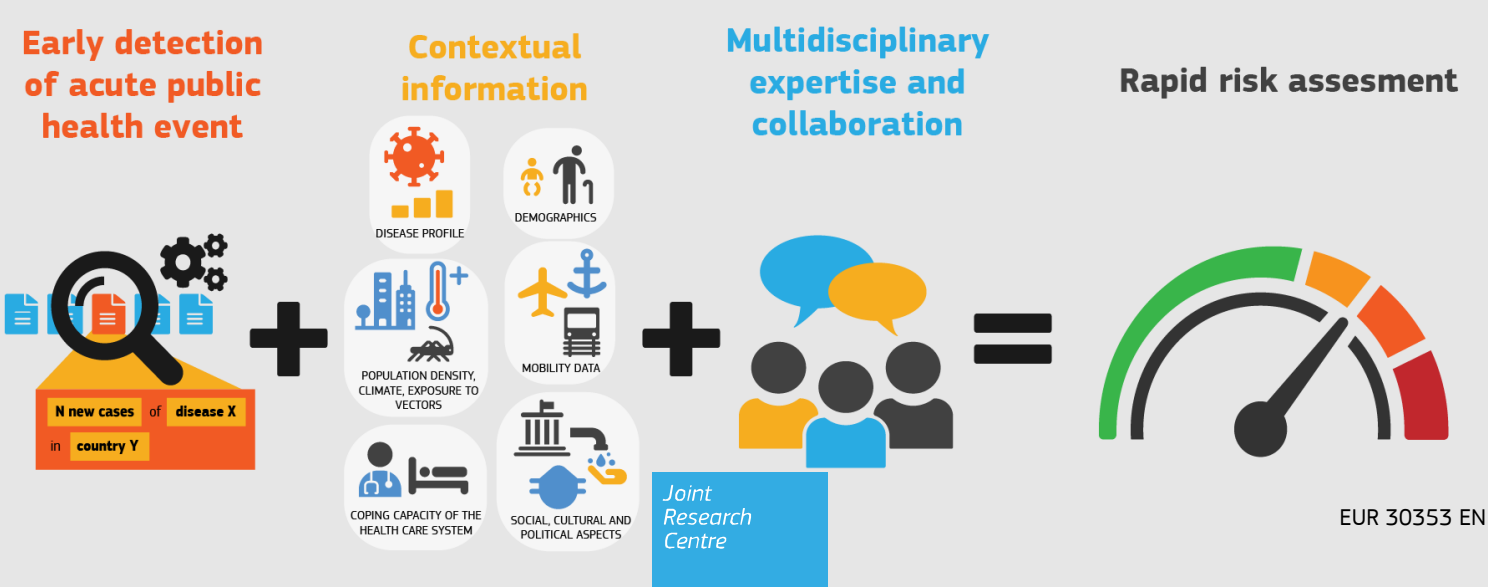

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Contact information
Name: Montserrat Marin Ferrer
Address: Via E. Fermi, 21027 Ispra (Italy)
Email: Montserrat.marin-ferrer@ec.europa.eu

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Abstract

The coronavirus disease 2019 (COVID-19) pandemic event has shown how communicable diseases can spread faster and further than ever before because of globalisation. The early detection of threats plays a crucial role in reducing their impact. It is essential to combine alert systems with contextual information to trigger adequate measures that may prevent or mitigate the risk in a timely manner. This report illustrates how early warning and rapid assessment activities can be supported by the systematic collection and analysis of publicly available information from official sources and the media.

Foreword

This report is a vision paper that, after showcasing recent developments, provides an insight into how to improve early detection tools for better decision-making in the frame of an integrated process for risk management based on collaborative efforts.

Authors

Spagnolo, Luigi ([1])

AbdelMalik, Philip ([2])

Doherty Brian ([3])

Fabbri, Marco ([4])

Jens Linge ([3])

Marin Ferrer, Montserrat ([1])

Moussas, Charalambos ([1])

Osato, Francesco ([5])

Petrillo, Mauro ([4])

Poljanšek, Karmen ([1])

Schnitzler, Johannes ([2])

Vernaccini, Luca ([6])

([1]) European Commission, Joint Research Centre, Unit JRC.E.1 Disaster Risk Management Unit

([2]) World Health Organization, WHO Health Emergencies Programme, Health Emergency Information and Risk Assessment, Information Systems and Analytics

([3]) European Commission, Joint Research Centre, Unit JRC.I.3 Text and Data Mining

([4]) European Commission, Joint Research Centre, Unit JRC.F.7 Knowledge for Health and Consumer Safety

([5]) Uni Systems S.R.L., external service provider of the European Commission, Joint Research Centre

([6]) Fincons S.p.A. external service provider of the European Commission, Joint Research Centre

1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic event has shown how communicable diseases can spread faster and further than ever before because of globalisation. The early detection of threats plays a crucial role in reducing their impact. It is essential to combine alert systems with contextual information to trigger adequate measures that may prevent or mitigate the risk in a timely manner. This report illustrates how early warning and rapid assessment activities can be supported by the systematic collection and analysis of publicly available information from official sources and the media.

This report is a vision paper that, after showcasing recent developments, provides an insight into how to improve early detection tools for better decision-making in the context of an integrated process for risk management based on collaborative efforts.

The effective **management of data, information and knowledge** is a critical challenge. Yet, existing knowledge remains scattered, and the generation of new knowledge is still an uncoordinated effort. Although some institutions have effective knowledge management strategies, knowledge is not always shared among them. The multiplicity of information sources/providers, systems, repositories and databases is costly, and it undermines the quality, timeliness, interoperability and traceability of data, resulting in duplication and inconsistency.

One of the key challenges for better regulation is ensuring that **evidence is available to support impact assessments and decision-making.** This calls for better anticipation of what future policy developments may require in terms of evidence. Moreover, linkages between policy areas (e.g. energy, environment, health) require a holistic approach to deliver a comprehensive answer to societal challenges.

To address these challenges, the Commission officially endorsed the concept of **knowledge centres** in its Communication on Data, Information and Knowledge Management (European Commission, 2016). These centres bring together experts and knowledge from different locations inside and outside the Commission, creating a new instrument to develop and pursue informed and evidence-based EU policies.

This report illustrates the work carried out in the context of the **Disaster Risk Management Knowledge Centre** to establish solid **partnerships at global level** by offering as common ground sound scientific tools that allow the different institutions to reach a common understanding and contribute to a common goal.

Within the framework of the **all hazards** approach and aiming to encourage an **integrated risk management**, this report presents the first steps towards bridging the gap between two global partnerships in virtue of more integrated scientific tools.

Coordinated by the World Health Organization (WHO), the **Epidemic Intelligence from Open Sources (EIOS)** initiative brings together new and existing partnerships, networks and systems to create a unified and multi-disciplinary approach to early detection, verification, assessment and communication of public health risk using publicly available information.

Following a long-standing collaboration with WHO, the European Commission's Joint Research Centre (JRC) leads the continuous scientific development of the EIOS information technology (IT) system that supports the **collaborative surveillance ad analysis carried out by the EIOS community of public health experts.**

In 2013, under the scientific lead of the JRC, **INFORM** ([1]) started to develop and publish a global INFORM Risk Index (De Groeve et al., 2014). Since then, INFORM has become a multi-stakeholder forum for developing a shared analysis **to help to manage humanitarian crises and disasters.** INFORM has partners from across the United Nations system, donors, civil society, the academic/technical community and the private sector. The INFORM Risk Index is a widely recognised and valuable tool that supports the decision-making of INFORM partners and other stakeholders.

INFORM partners believe that the availability of a shared analysis of crises and disasters can lead to better coordination between stakeholders and better outcomes for at-risk and affected people. Specifically, INFORM creates a space and a process for a **shared analysis that can support joint strategy development,** planning and action that can prevent, prepare for and respond to crises. This can bring together development, humanitarian, and other stakeholders so that they can manage risk and respond better when crises do occur.

([1]) https://drmkc.jrc.ec.europa.eu/inform-index

Key conclusions

A main priority for the EIOS system is the integration of additional contextual knowledge (including demography, environmental factors, migration and movement patterns, and coping capacity of health systems) to better support the rapid risk assessment of early identified threats and, subsequently, faster and more effective decision-making.

The integration of the contextual information produced under the INFORM umbrella as input for the EIOS collaborative platform could favour **strengthened cooperation between the two communities behind these collaborative platforms.** On the other hand, a more dynamic assessment of the risk of a humanitarian crisis taking advantage of the expertise developed by the EIOS collaborators could be of clear interest to the humanitarian aid community.

As a candidate for the initial integration of such contextual information, the INFORM suite appeared to be a very suitable choice. INFORM features a suite of quantitative analysis tools – among which the INFORM Risk Index is the most consolidated – combining several indicators to assess exposure to hazards (including epidemics), vulnerability and coping capacity of countries and subnational areas.

As a demonstration of its adaptability to the health domain, INFORM Risk Index has also been successfully adapted to develop specific country profiles assessing the risk of epidemics in general and COVID-19 outbreaks in particular, which could exceed national capacity to respond to the crisis.

The results presented in this report are expected to be the initial step towards a more comprehensive approach. Several additional opportunities for further development are mentioned in the light of a reinforced risk and crisis management.

Main findings

The INFORM Risk Index has been successfully integrated into the current EIOS workflow, providing additional insights when exploring specific contexts of monitoring and analysis, such as those linked to a specific disease in a given area of the world. INFORM metrics are visualised to indicate which aspects in the specific countries are particularly critical (e.g. the presence of vulnerable groups, and high exposure to human-to-human transmissible diseases).

Moreover, the same indicators can be used to prioritise public health intelligence tasks, for example focusing on the most vulnerable countries. This early integration is a promising demonstration of the potentialities of the tool.

A wise combination of **artificial intelligence (AI)** tools – ones that are able to support the early detection process in a suitably dynamic way –, and **contextual information** – to provide a more static but solid overview about pre-existing conditions –, in the hands of a **network of experts** on public health and crisis management will make a notable difference.

Related and future Joint Research Centre work

Further integration of contextual knowledge is envisaged. An important aspect to be taken into account is that different diseases may have specific features that make certain countries more or less at risk in a given scenario, and therefore different containment measures may be required.

The INFORM framework is flexible enough to be adapted to different diseases by combining the most appropriate indicators. A comprehensive library of those indicators should be built, in collaboration with WHO and possibly other scientific partners to cover a wide range of scenarios. Moreover, information about past events may also help identifying the most effective containment measures to be prescribed in a specific case.

Finally, integration with other systems in use for rapid risk assessment at WHO and other EIOS stakeholders such as the European Centre for Disease Prevention and Control (ECDC), is also an opportunity to improve and cross-fertilise systems to better support knowledge exchange and more informed decisions.

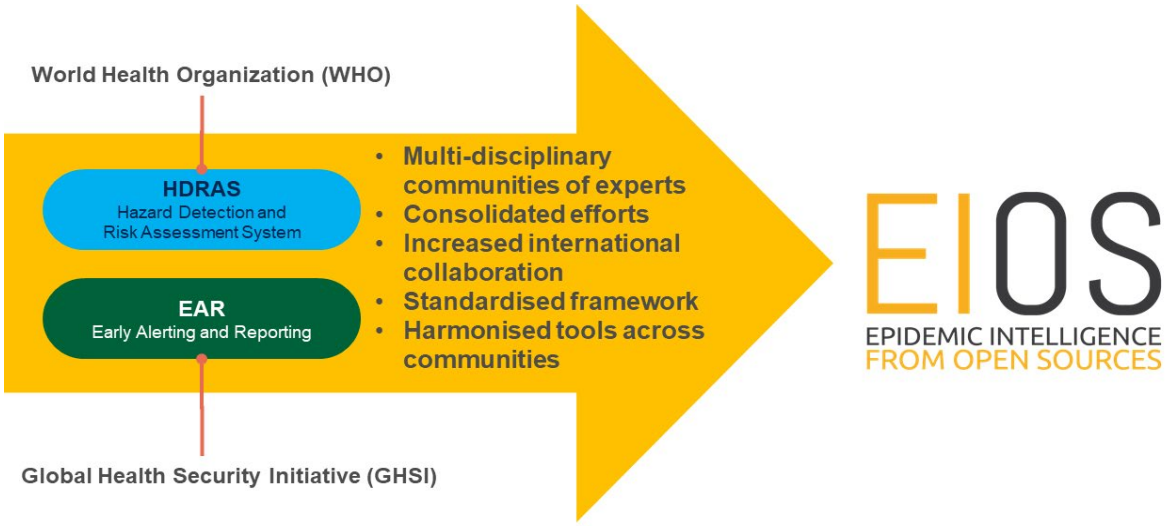
2 Background

2.1 The need for public health intelligence

As demonstrated by the COVID-19 crisis, communicable diseases – especially those caused by respiratory pathogens – can spread further and faster across countries and continents than ever before, in large part because of increased global travel and trade. In the last decades, other diseases such as influenza, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), Ebola, Zika, plague and yellow fever have been examples of high-impact, fast-spreading diseases causing frequent outbreaks that are increasingly difficult to manage. Megatrends such as increased urbanisation and population growth, climate change and other environmental issues may also augment the risk of threats having a potentially high cost for human health and a severe impact on economies and societies (Global Preparedness Monitoring Board, 2019)

In rapidly evolving situations, early detection and assessment of potential public health threats play a crucial role in triggering appropriate measures that may prevent or mitigate the risk in a timely manner. Systematic collection and analysis of any relevant publicly available sources of information – including media - are key to better supporting an early detection of public health threats (WHO, 2014).

Figure 1. The EIOS system is the latest step of a long-lasting collaboration between the European Commission's JRC, the WHO and the Global Health Security Initiative.



Source: JRC, 2020.

In 2008, the Global Health Security Initiative (GHSI) endorsed the development and piloting of the Early Alerting and Reporting (EAR) platform for monitoring, detecting and relaying critical information to decision makers about emerging chemical, biological, radiological and nuclear (CBRN) threats, as well as pandemic influenza threats. The platform was developed by the JRC based on the European Media Monitor (EMM) and the Medical Information System (MEDISYS) technlogies (Linge et al., 2009) and made possible through significant financial and in-kind contributions from GHSI members and the European Commission. The EAR project demonstrated the value of bringing together stakeholders from the international community, building on existing surveillance systems and establishing a trusted network of expertise.

In 2013, the JRC used internal support and resources, as well as support and resources from the European Commission, to develop an information and communications technology platform for the WHO: the Hazard Detection and Risk Assessment System (HDRAS). The HDRAS platform was developed based on the same technology as used for the EAR platform mentioned above. Its purpose was to facilitate the detection and ongoing monitoring of acute public health events and support daily collaboration and information sharing across all WHO levels.

The complementarity of the EAR and HDRAS systems, the fact that they were sharing the same underlying technology built by the JRC, and the need to consolidate efforts and platforms across organizations were key drivers of the establishment of the **EIOS Initiative** in late 2017 (see Figure 1). Today, the EIOS initiative is a

WHO-led network of public health organizations and experts that aims to improve global health and reduce the disruption to communities and economies through early warning for rapid response. The EIOS system – a web platform developed by the JRC – helps analysts and experts to readily identify and analyse health-related publicly available information, as well as to communicate and collaborate with each other to detect, verify and assess potential health threats as early as possible.

2.2 Knowledge for risk assessment as a key priority

In December 2018, during the first EIOS Global Technical Meeting held in Geneva, one of the top four priority areas identified by EIOS stakeholders for developing additional technical tools and solutions in the EIOS system was that of **risk assessment and contextual information**. Appropriate response and action based on public health intelligence require the evaluation of known and potential threats to estimate associated risks. **Appropriate risk assessment requires contextual knowledge of many different aspects**, such as health care systems, burden of disease, demography, weather, built and natural environments, and migration and movement patterns. The ability to tap into diverse data sources – whether through acquisition and curation, collaborative exchange or some other mechanism – creates a rich data ecosystem for building knowledge, adding context and confidence to the risk assessment process and enhancing capacity for predictive analytics.

One such source of information is the **INFORM Risk Index**. The INFORM Risk Index is a composite indicator developed by the JRC that identifies countries at risk of humanitarian crises and disasters globally. In the 2019 release, an epidemic hazard component was added.

In response to the COVID-19 pandemic, the JRC released an adapted version of the INFORM Risk Index specific to **COVID-19** to support the decision-making needs of humanitarian and other organisations. Furthermore, the INFORM Risk index is only one of the products of the INFORM suite, alongside the INFORM Warning tool and INFORM Severity Index, which together facilitate decision-making at different stages of disaster management. All three tools have shown the flexibility required to support the needs of different partners in relation to COVID-19.

The INFORM Risk Index (and its adapted versions for addressing COVID-19 and epidemic risk) appeared a natural initial choice to start addressing the requirement of the EIOS community for incorporating useful contextual information into the system. INFORM is an appropriate and relevant data source and, as the EIOS system, is developed by the JRC, thus facilitating the development efforts required for integrating the two tools. The integration of these risk indices into the EIOS system is the **first step to empowering the early warning system with risk assessment capabilities.**

However, the appropriate assessment and response to any event depends on a broader and more specific knowledge of the context within which the event is occurring. Depending on the event, information from different areas or sectors may be needed, and therefore more relevant data sources may need to be incorporated into the EIOS system for effective multi-hazard rapid risk assessment.

The specific way in which the current INFORM data have been integrated, presented and visualized in the EIOS system, as well as the various lessons learned during the implementation of the corresponding end-user interface, represent a valid and useful background for any additional contextual information development activities in the EIOS system.

3 Becoming more resilient through collaborative approaches to Risk Management

3.1 Epidemic Intelligence from Open Sources

The **EIOS initiative** ([2]) is a collaboration between **several public health stakeholders worldwide** (see Annex I), bringing together a number of new and existing initiatives, networks and systems to implement a unified approach to the early detection, verification, assessment and communication of public health threats using publicly available information.

The approach builds on the **all hazards**, **One Health** principle, that is, the idea that human, animal and environmental health are correlated and that all possible sources of public health risk should be comprehensively monitored, enhancing collaboration and communication between communities of experts with different focuses, expertise and mandates. Two elements are at the heart of the initiative:

- A **community of practice for public health intelligence**, under the leadership of the WHO, including Member States, international and regional organisations, and other partners and collaborators.
- An **IT system** collaboratively developed under the scientific and technical lead of the JRC. The system supports the community of practice in its active performance of the public health intelligence function, not only by extracting article information from publicly available on-line sources, but also by including information from other public health intelligence tools. It collects several thousand articles per hour, automatically classifying them according to potential threats and other topics that are relevant to public health (e.g. measures taken, disease symptoms and outcomes). Eventually, it makes this large amount of information available to the community of analysts for monitoring and assessment.

In the COVID-19 context, the detection of the outbreak can be considered a success story for the EIOS initiative. In fact, the EIOS system picked up the first signal of the pneumonia cluster in Wuhan, Hubei Province of China, at 3:15 am Coordinated Universal Time on the 31st of December 2019. The signal came directly into the EIOS system from a media source ([3]) and within a short time frame, was complemented by other reports from systems connected with the EIOS system (ProMed, Global Public Health Intelligence Network – c, HealthMap), as well as through notification to WHO by the Chinese authorities. Necessary assessment and verification processes were immediately set in motion between the EIOS communities to assess the risk of spread. This example highlights the philosophy behind the EIOS initiative, underlining the value of collaboration rather than viewing early detection as a competition. The strength of the EIOS initiative lies in combining and connecting systems, stakeholders and expertise to pick up signals early and allow a quick assessment, verification and response, to save lives and to protect global health security overall.

However, whatever the context, it is important to emphasize that the EIOS system does not replace established formal communication and reporting channels, such as those put in place under the International Health Regulations, under which all WHO Member States are obliged to formally report health threats that meet certain criteria. Rather, the EIOS system is a set of tools that allows analysts to use other sources of information – namely, publicly available information – to complement traditional surveillance data, to identify and assess potential events that may pose a threat to public health more quickly, and to further facilitate communication across the network of health experts worldwide. Thus, the EIOS initiative aims to **augment human expertise and existing relationships**, not to replace them.

Today, typical tasks performed by the users of the EIOS system include the following:

- event-based surveillance (EBS) for the identification of new public health threats and monitoring of ongoing threats based on an all hazards approach
- collating updates to communicate to colleagues and partners
- monitoring public health measures
- collaborating and communicating with the network through the EIOS system
- gathering information on vaccine development

([2]) www.who.int/eios
([3]) https://www.cna.com.tw/news/ahel/201912310041.aspx

— including official government sources for verified information and cross-validation

— analysing the impact of COVID-19 on other public health activities

— monitoring impact on the health care system

Most of these tasks contain a strong collaboration component that is in line with the vision of the EIOS initiative. Rapid response to global threats requires a global community of health experts exchanging information and working collaboratively on solutions provided by science and technology that are able to address its needs. This is why collaboration is the cornerstone of the EIOS initiative. Current and future technical developments of the EIOS system are therefore geared towards enhancing collaboration and information sharing between EIOS stakeholders by implementing various new features such as:

— the implementation of a shared workspace across communities for joint monitoring of events

— more granular management of permissions (what can be seen/edited /shared by whom)

— community-shared dashboards visualizing summary information and geographical aggregations

— an improved workflow for information exchange on potential signals between communities

— improved reporting and communication functionality

— tools for collaborative rapid risk assessment: data visualization and exploration, support for standard operation procedures, reports and notifications

— visual analytics for social media

— the identification and classification of mis- and dis-information

— the development and integration of new tools and approaches through collaborations with the private sector and academia

— the integration and sharing of contextual information

— the broadening of geographical and language coverage

— the addition of new categories in view of the One Health approach (e.g. plant health, animal health, chemicals, etc.) and to capture other aspects (disease outcomes, stages of outbreaks, etc.)

— the inclusion of additional sources, for example audio (speech to text from radio and video)

In all these areas, the JRC has been conducting research and development activities for the last 20 years in the broader fields of open source information mining and analysis, integrated systems for collaborative risk analysis and crisis management technologies. Applications built around the JRC's research serve risk and crisis management needs such as threat detection, situational awareness, early warning and collaborative decision making. Furthermore, as the science and knowledge service of the European Commission, the JRC's mission is to support EU policies with independent evidence throughout the whole policy cycle. Therefore, through a successful continuation of the collaboration between WHO and the JRC, new collaborative approaches can be identified and developed in the areas of early warning and rapid risk assessment, further contributing to the successful implementation of the EIOS initiative worldwide.

3.2 INFORM

INFORM is a set of three products (Figure 2) that together support decision-making at different stages of the disaster management cycle, specifically prevention, preparedness and response:

— The **INFORM Risk Index** is the first global, objective and transparent tool for understanding the risk of humanitarian crises and disasters. It can help identify where and why a crisis may occur so that organisations can respond rapidly to reduce the risks, build peoples' resilience and prepare better for times of crisis.

— The **INFORM Warning Tool** is intended to provide common, shared, quantitative information that can be used in risk monitoring for preparedness, early warning and early action processes. It collects, aggregates and presents information on crisis-related risks that are dynamic rather than structural or persistent in nature - in other words, changes in risk that occur over a period of less than 1 year.

— The **INFORM Severity Index** is an improved way to objectively measure the severity of humanitarian crises globally. It can help develop a shared understanding of crisis severity and ensure that all those affected get the help they need.

INFORM develops methodologies and tools for use at the global level and also supports their application at subnational levels.

The development of all INFORM products follows the same principles:

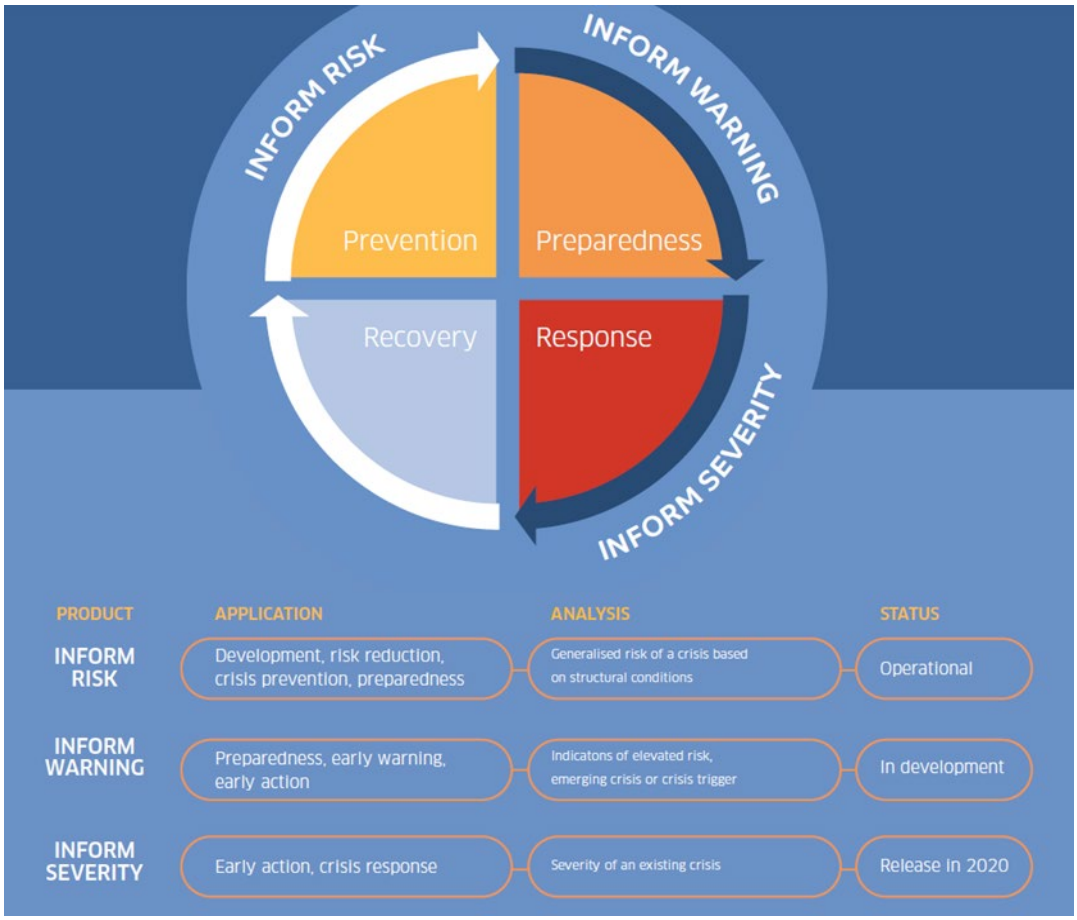
— **Global.** INFORM global products cover 191 countries and sub-national products include all parts of the region or country they cover.

— **Open.** All INFORM products are freely available and the methodology and sources are open and transparent.

— **Reliable.** INFORM products use the best available methods and data. INFORM partners are committed to making them available in the long term.

— **Flexible.** INFORM products can be easily adapted and included in the decision-making processes of users.

Figure 2. INFORM's vision for a suite of products to support decision-making



Source: Thow et al., 2020.

INFORM's approach and products are increasingly recognised to support several key components of the post-2015 humanitarian, Disaster Risk Reduction (DRR) and development agenda. **Shared analysis and joint humanitarian and development actions** are principles recognised by the World Humanitarian Summit outcomes, the Sendai Framework and the Sustainable Development Goals.

According to INFORM partners, the availability of a shared analysis of crises and disasters can lead to better coordination between stakeholders and **better outcomes for at-risk and affected people**. More specifically, the space and process needed for a shared analysis that is created through the INFORM framework can support joint strategy development, planning and action for prevention, preparedness and response to crises. This allows

development, humanitarian and other stakeholders to be brought together, to manage risk and respond better to emerging crises (Thow et al., 2020).

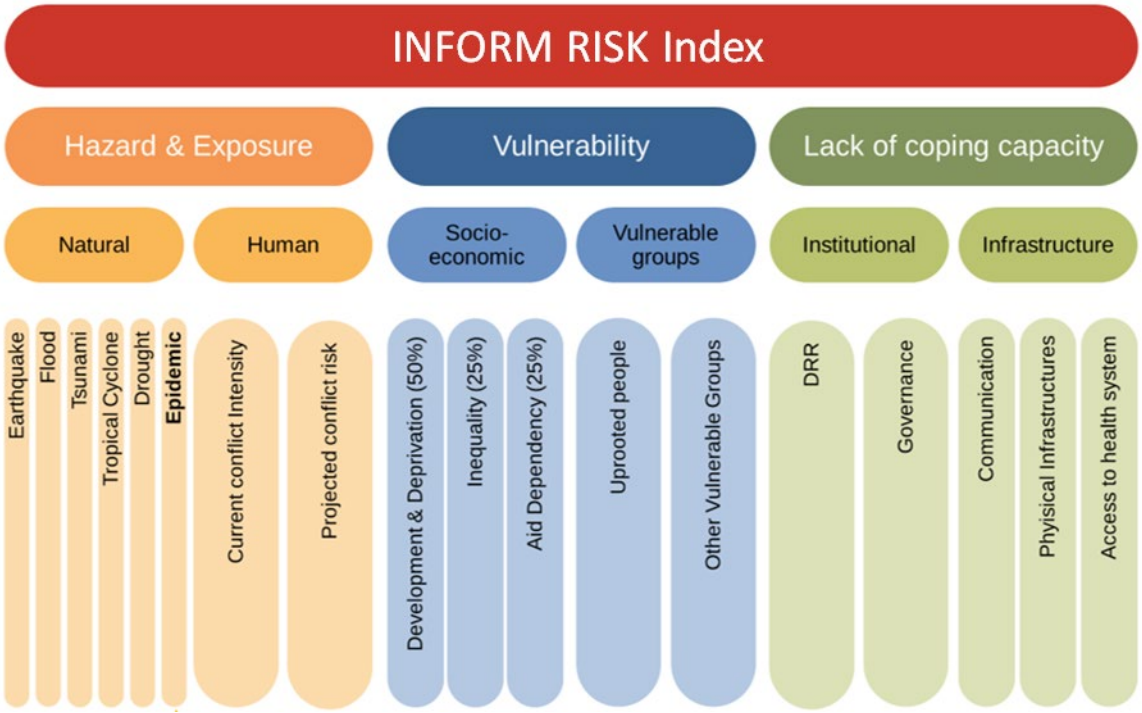
3.2.1 INFORM Risk Index

The INFORM Risk Index is a tool for identifying countries or areas of countries at risk of humanitarian emergencies that could overwhelm national response capacity and lead to a need for international assistance. It supports objective, risk-based decisions to help prevent, prepare for and respond to crises and disasters, and build resilience. It is used by, among other groups, governments, humanitarian, development and DRR sectors. The year 2020 marks the seventh annual release of the global INFORM Risk Index.

Using the INFORM Risk Index allows countries to be prioritised by risk, or any of its components, to decide how best to reduce risk and to monitor risk trends.

The INFORM Risk Index is based on risk concepts. The model (Figure 3) consists of three dimensions: hazard and exposure, vulnerability and lack of coping capacity. The INFORM Risk Index simplifies information about risk using 50 different indicators, creating a risk profile for every country. Each has a risk rating between 0 and 10 for easy comparison, with 10 representing the highest risk.

Figure 3. The analytical framework of the INFORM Risk Index

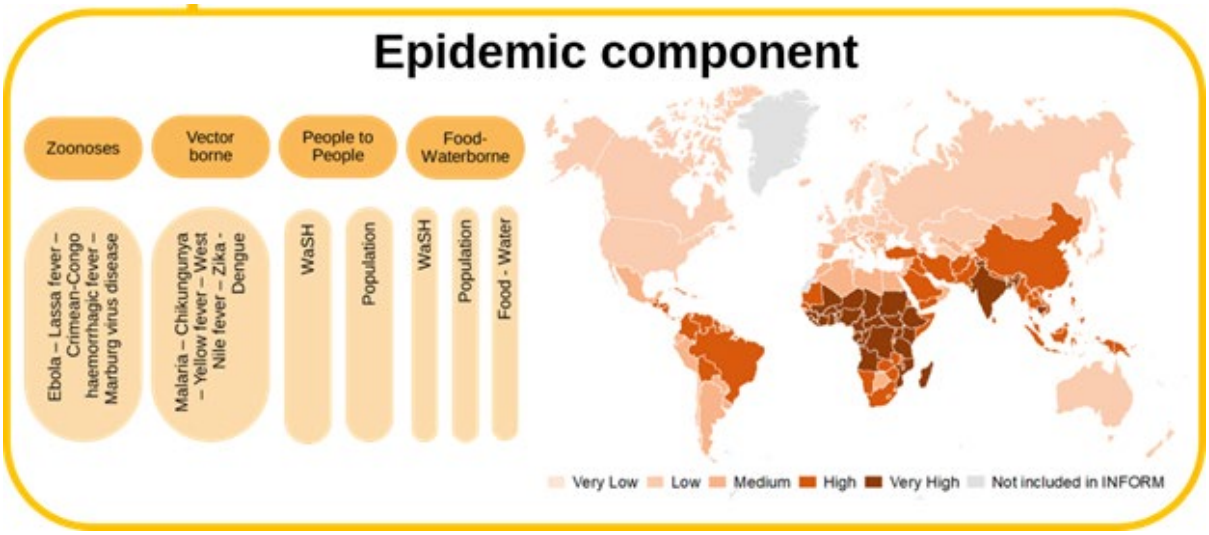


Source: Poljanšek et al., 2018.

In the sixth release of the INFORM Risk Index, in 2019, an **epidemic hazard component** (Figure 4) was added. For the first time, within a single framework, the INFORM Risk Index allows the assessment of epidemics in a multi-hazard risk assessment framework at the global level (Poljanšek et al., 2018). This new epidemic component identifies areas with a possible presence of various pathogens and the populations exposed to them, thereby modelling conditions where outbreaks could start. The development of this component benefited from existing models for the transmission of a virus from environmental sources to human populations to establish regions at risk of spillover infections. To calculate the potential exposed population, the **Global Human Settlement (GHS) Population Grid** was used to estimate the numbers of individuals exposed within each country.

The GHS population grid (Freire et al., 2016; Schiavina et al., 2019) fits all the INFORM's requirements, as it is global in coverage and an open source, and has a transparent methodology and high resolution.

Figure 4. Epidemic component in the Hazard & Exposure dimension of the INFORM Risk Index



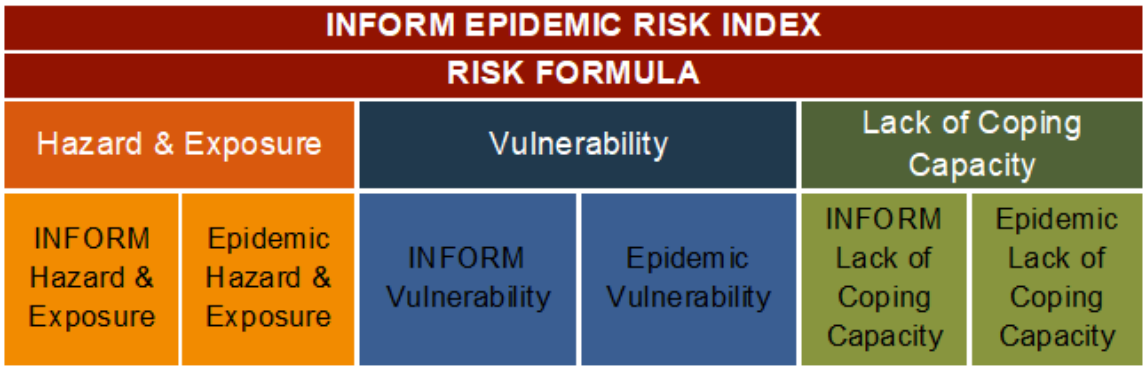
Source: Poljanšek et al., 2018.

3.2.2 INFORM Epidemic Risk Index

The INFORM Risk Index methodology is very flexible and it can be adapted to specific focus areas. In 2018, the JRC developed the INFORM Epidemic Risk Index in close collaboration with WHO. Through extensive consultation, WHO experts identified the underlying risk drivers of epidemics, which enabled the development of a conceptual framework for epidemic risk assessment in countries (Figure 5).

The INFORM Epidemic Risk Index (Poljanšek et al., 2018) assesses the risk to countries of outbreaks, that would exceed national capacity to respond to the crisis.

Figure 5. The analytical framework of the INFORM Epidemic Risk Index



Source: Poljanšek et al., 2018.

4 Collaborative early detection for rapid reaction

As mentioned, early detection and monitoring can play a crucial role in reducing the impact of health threats and saving lives by triggering and informing appropriate rapid response. For instance, the early detection of sustained **local transmission of SARS-CoV-2 in Europe** led certain countries to rapidly implement travel restrictions and lockdown measures, resulting in a lower number of COVID-19 casualties by population (e.g. see Conyon e al. 2020, Moris and Schizas, 2020).

Depending on the specific public health threat, and the risk associated with it, different early preparedness and response measures can be taken. For example, as a first step, a specific situation be simply be put under stricter surveillance to better monitor its development. In other cases, more strict early reactions may be suggested at different levels, such as social distancing, protective equipment and travel restrictions.

Early and detailed information allows for **adapted measures** and supports planning and preparedness including stockpiling and the deployment of medical equipment and testing kits, and the reorganization of the health system.

4.1 Supporting the public health intelligence function

The EIOS system enables and supports the whole public health intelligence function, with particular focus on early detection. As illustrated in Figure 6, public health intelligence encompasses several activities that are discussed further in the following paragraphs. Although in the figure these are represented as a cycle for the sake of simplicity, it is important to stress that these activities are inevitably continuous and parallel in nature.

Figure 6. Public health intelligence activities as supported by the EIOS system

Source: JRC, 2020.

4.1.1 Monitoring

This continuous activity involves reviewing of information available through the EIOS system to find potential signals of public health threats. A **monitoring and analysis scope of interest** may focus on **specific routine surveillance** (e.g. priority diseases and sources) or be triggered by **specific ongoing events** such as the COVID-19 pandemic and other outbreaks, or by other issues.

During the first few months of the COVID-19 crisis, more than 100,000 articles related to COVID-19 were made available to EIOS community analysts through the system on a daily basis from more than 11,000 sources (including mass media, scientific journals, national and local health authorities, and as other systems and networks collaborating on EIOS). This was in addition to tens of thousands of articles related to other potential health threats, all of which were automatically classified by the system based on almost 400 categories defined in multiple languages.

Since the volume of information is huge (especially during pandemics or large events), **analysts need to work collaboratively (i.e. in teams)** and define **specific scopes for monitoring and analysis** by combining different filters, as discussed in Section 4.2.

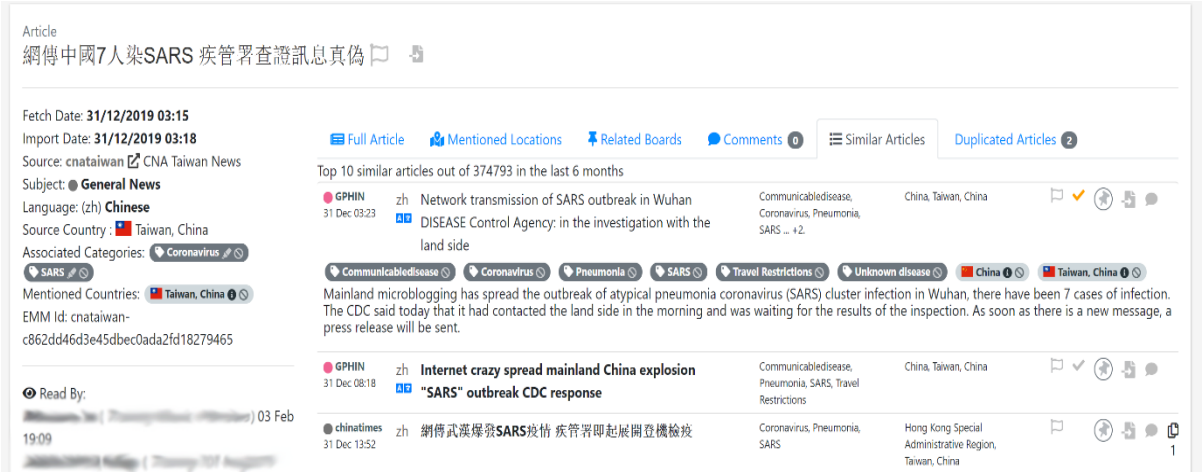
Future developments on the EIOS system coping with the challenges of this phase are discussed in Section 4.4.

4.1.2 Detection and verification

Once specific content or information captures the attention of experts (e.g. it highlights a potential health threat), its reliability and significance needs to be verified, especially in the light of the increasing phenomenon of misinformation and disinformation (which is also discussed in Section 4.4).

Verification can be achieved in different ways on the EIOS system: first, users can look at **similar current and past articles** suggested by the system (see Figure 7); second, they can **modify the current scope of analysis** (by changing the filters) to see if other reports available in the system confirm or contradict the identified signal; and finally, teams of analysts can use the **communication tools** available to post comments and exchange information with **other experts (potentially those of other disciplines and other institutions) using the platform** to request their advice or initiate further follow up.

Figure 7. The first article about a SARS-cov-2 outbreak in Wuhan detected by the EIOS system ([4]). The list of similar articles received subsequently confirmed the early report.



Source: EIOS system, 2020.

4.1.3 Rapid risk assessment and communication

Once a potential health threat has been detected and verified, a rapid assessment of the possible public health risk is needed to inform subsequent action. Experts with different interests (human health, animal health, CBRN, security, etc.) may adopt different methodologies and define different criteria (likelihood and impact of possible spread, etc.) to be taken into account. Depending on the underlying hazard and situation, the experts may need different contextual information.

At present, through the EIOS system's user interface, information about risk assessment can be exchanged by using the communication tools available in the system, but more structured solutions are envisaged for the future (see Section 4.5).

Moreover, in Chapter 6, we discuss how additional information (either already available or to be integrated in the system) can support analysts in assessing the potential risk as it provides them with a deeper understanding of the context.

This **contextual information** about the disease and the situation of the geographical area in which the cases are detected (in terms of mobility, demographics, coping capacity of the health care system, etc.) should complement the knowledge of the signals coming from the **monitoring and analysis scope**.

Finally, the assessed source of risk must be communicated outside the platform to suggest potential actions to be taken. To report the outcome of their analysis, EIOS users can take advantage of the aforementioned **communications tools**, as well as **automatic notifications and digests** sent to distribution lists. For the future, more advanced reporting tools and integration with other systems (such as the WHO Emergency Management Suite) are also envisaged.

([4]) Its title could be translated as "It is reported that seven people in China are infected with SARS".

4.1.4 Triggering and monitoring preparedness and response actions

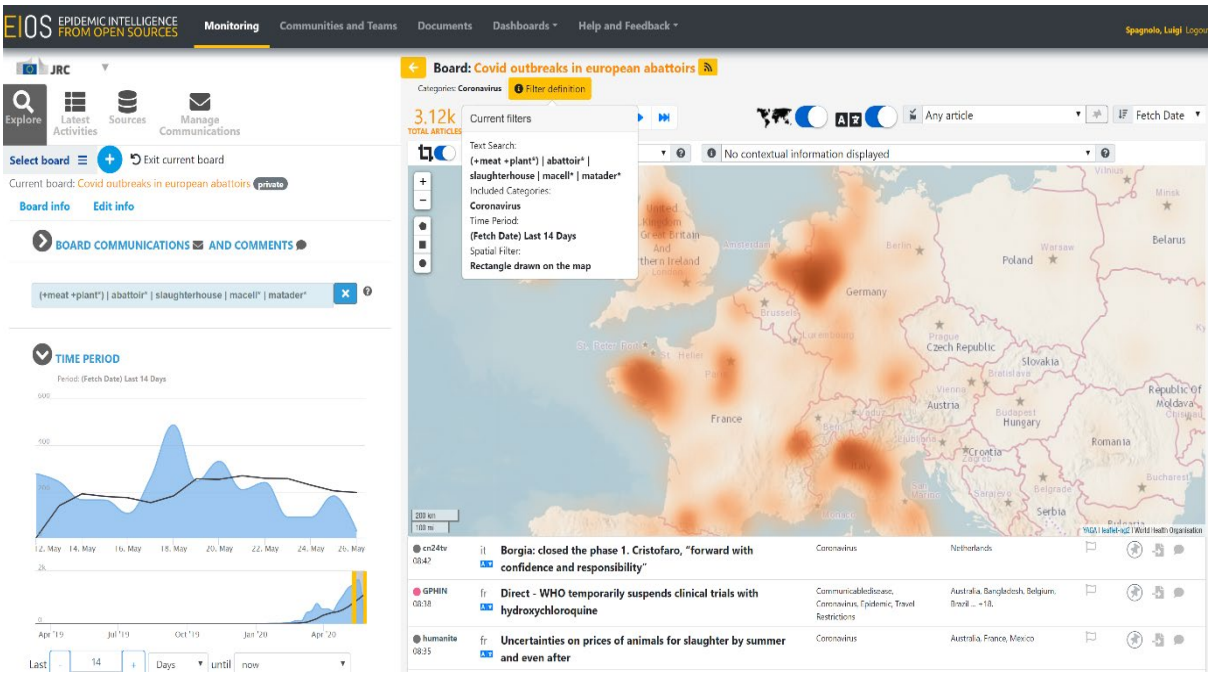
As Figure 6 illustrates, identified signals can eventually trigger specific **preparedness and response actions**. The implementation of those actions can, in turn, be monitored using the system to follow the development of the crisis, therefore going back to the first stage of the public health intelligence continuous process.

4.2 Defining the monitoring and analysis scope of interest: exploring different dimensions

4.2.1 Examples of monitoring and analysis scope

As discussed in Section 4.1, the **monitoring and analysis scope of interest** is fundamental to supporting the different phases of the public health intelligence function in the system. This allows analysts to focus on their specific interests and concerns.

Figure 8. EIOS portal interface: articles mentioning possible COVID-19 cases in abattoirs in Europe, with a moving window covering the previous 14 days.



Source: EIOS system, 2020.

Examples of **monitoring and analysis scopes** include the following:

— evolution of **specific disease outbreak(s)**, globally or in a specific area, for example 'COVID-19 Global Monitoring', 'COVID-19 in the WHO European Region', and 'Ebola in the Democratic Republic of Congo';

— analysis of very **specific issues, such as particular symptoms or situations** connected to an outbreak, for example 'Kawasaki syndrome in children', 'microcephaly caused by Zika virus', 'COVID-19 cases in abattoirs' (see Figure 8), and 'COVID-19 cases and migration crisis';

— **routine surveillance**: for example 'WHO priority diseases to monitor beside COVID-19', and 'World Organization for Animal Health (OIE) diseases';

— Surveillance around **mass gathering events** attracting people (e.g. athletes, tourists) from different countries, for example 'FIFA World Cup ([5]) 2018 in Russia';

([5]) International football competition organised by the Fédération Internationale de Football Association (FIFA)

— detection of **unknown diseases** with certain characteristics (in terms of symptoms, outcomes, infectivity, etc.) that may pose a significant risk to public health and require further investigation (e.g. novel coronaviruses or other lethal respiratory pathogens);

- research and retrospective analysis, for example 'Influenza cases in 2019'.

Information about specific events and scopes for monitoring and analysis, including filters and rationale, can be saved for ongoing or subsequent use and sharing.

4.2.2 Available dimensions

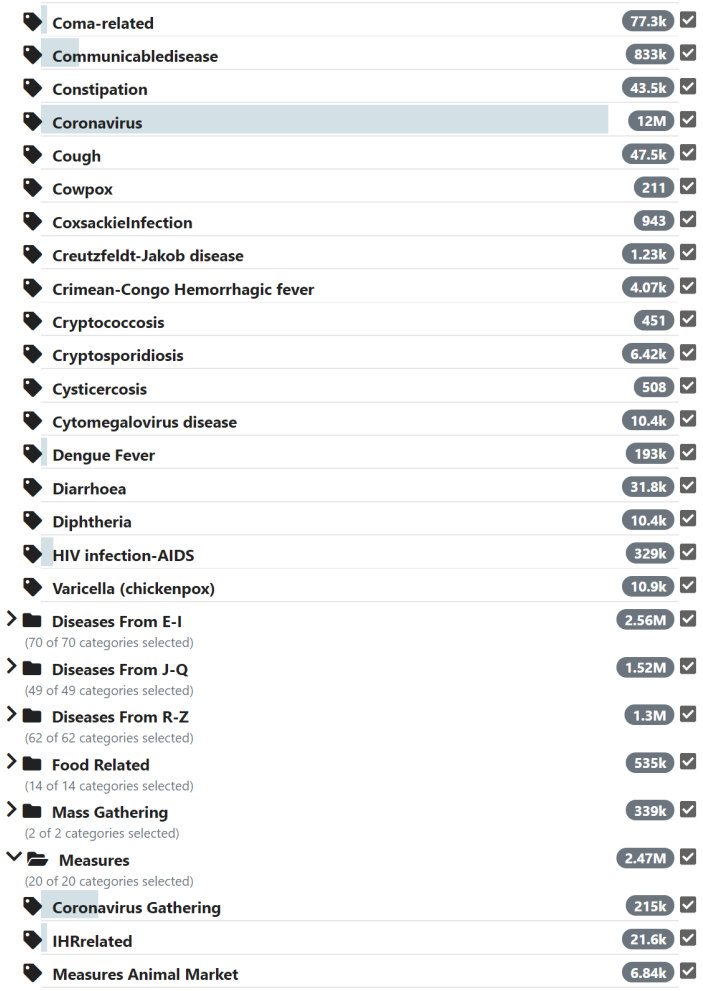
In the EIOS system, a monitoring and analysis scope can be defined by **combining filters across different options and dimensions**, as described in the following paragraphs.

4.2.2.1 Categories

Categories are specific concepts mentioned in the text, according to which articles are automatically classified by the system. They include various diseases (e.g. 'Coronavirus infection', 'Ebola', 'Cholera', and 'disease of unknown origin'), symptoms, public health measures (e.g. 'travel and trade restrictions'), other hazards that may trigger public health issues (e.g. natural hazards, conflicts, CBRN threats), reference to mass gathering events, and other potentially relevant topics.

In Figure 9, an example of categories available in the system are shown as visualised in the user interface, The grey bar provides a visual clue to the category's frequency in the current monitoring scope, as expressed by the other filters applied.

Figure 9. Example of available categories, as visualised in in the system.



Source: EIOS system, 2020.

Categories are defined as combinations of keywords (in all the languages that have been defined) that should appear in the text and are used by the system algorithm for automatic classification. For example an article may be classified as 'Coronavirus infection' if it mentions keywords and expressions such as 'COVID-19' and 'SARS-like virus', or translations such as *Κορωνοϊός* ('coronavirus' in Greek).

Different organisations may be interested in different categories for their day-to-day surveillance (e.g. the World Organisation for Animal Health – OIE is clearly mainly interested in animal diseases). Given this, each organisation has a certain degree of freedom in selecting and organising the specific categories in which their public health experts may be interested.

4.2.2.2 Text search

Users are allowed to search for specific keywords (e.g. 'Kawasaki syndrome', 'abattoirs', and 'refugee camps', etc.) in the text of the article or in its automatic English translation (when provided by the system), thereby focusing on specific concepts that may not (yet) be covered by categories.

Text search looks for exact entries and or slight variants (e.g. plural/singular) in the specific language, whereas categories are designed to systematically cover a larger number of languages as well as possible synonyms in those language.

4.2.2.3 Mentioned countries and locations

Mentioned countries and locations are specific references to countries, cities or sub-national entities appearing in the text. Geographical filters can also be applied by drawing rectangles, polygons and circles on a map to focus on a specific area.

4.2.2.4 Article retrieval and import date

Analysts are allowed to filter by different time periods according to the date and time at which the specific item of information was retrieved and subsequently made available in the system.

In particular, they can filter by using a specific range of dates (e.g. 'from 1 January to 31 May'), or by specifying a 'moving' time window (e.g. 'last 14 days' or 'last 48 hours'). In addition, they can 'navigate' week by week or month by month to gain an understanding of how the situation is evolving, as illustrated in the example shown in Figure 12.

4.2.2.5 Source of information

Analysts can look at **specific sources** (e.g. 'Euronews', 'Swedish Ministry of Health', 'International Journal of Infectious Diseases') and/or sources by **subject** ('General news', 'Official medical sources', 'Medical news', etc.), and by the **language** and **country** of the source.

4.2.3 Example of exploration by space and time

In Figure 8, a screenshot of the EIOS system shows an example of a monitoring and analysis scope, used to investigate cases of COVID-19 detected among workers in European abattoirs, in a time window covering the previous 14 days.

As illustrated, the scope is defined by the following filters:

- text search – a reference to abattoirs and meat processing plants in some European languages (provided that some of them are also automatically translated into English by the system).
- categories – coronavirus
- time period – last 14 Days
- Spatial Filter – Rectangle drawn on the map (limiting the search to only European locations)

In addition to the list of articles satisfying the filters, the user interface features a chart reflecting the number of relevant articles by date, as well as an interactive heat map showing the distribution of mentioned locations.

These two tools can help analysts make sense of a large amount of information, by **visually indicating anomalies** (**peaks in the number of articles in the time chart** with respect to a moving average, and/or **hot spots in the map**) that may warrant further investigation.

Aggregated information could be affected by noise; for instance, several articles mentioning cases in abattoirs also refer to the situation in other severely hit regions of Europe in which no cases were reported in meat processing plants during the same period.

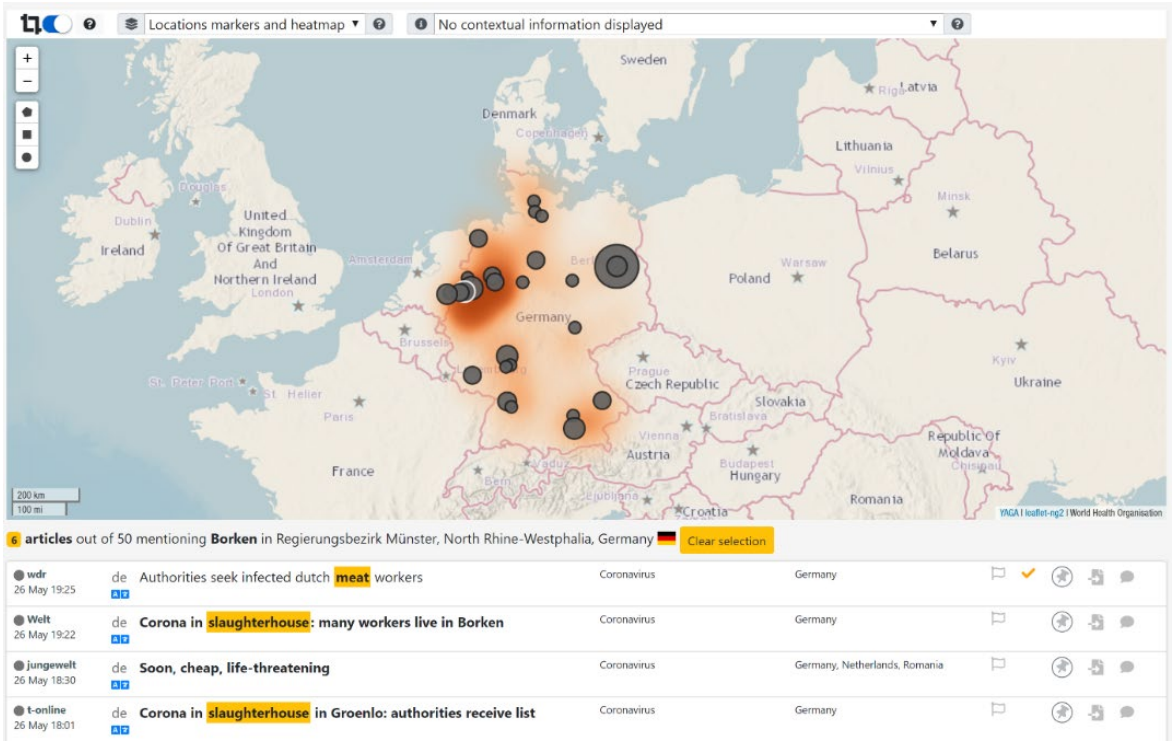
Still, the visualisation is able to capture where and when cases have occurred, **guiding the experts' analysis of the situation**. Users can focus on all articles mentioning a specific country and look at specific locations as they appear on the map (see Figure 10).

Analogously, by drawing a different square on the map, the user can focus on a specific sub-national area, and thus discover information about cases occurring in specific locations of that administrative region only (see Figure 11).

In addition, by interacting with the time chart and filtering by specific weeks, it is possible for the analysts to **have a grasp on how the situation has evolved** in terms of locations mentioned and media coverage (see Figure 12).

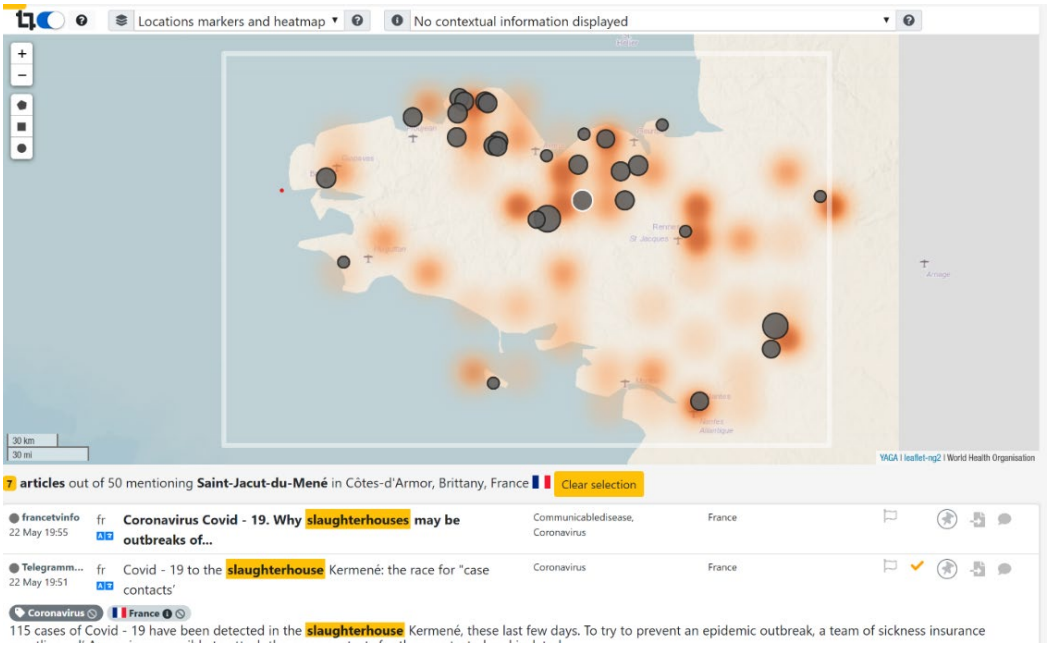
Other statistics are also computed and readily visualized while the filters re being changed, such as those about the sources covering the information being retrieved. For instance, the charts in Figure 13 show that cases in Brittany, France, are mainly covered by local, general media sources. Each option can be used to further filter the articles (e.g. only from sources in French and/or from France).

Figure 10. Map of locations mentioned in articles about possible cases of COVID-19 among workers in Germany.



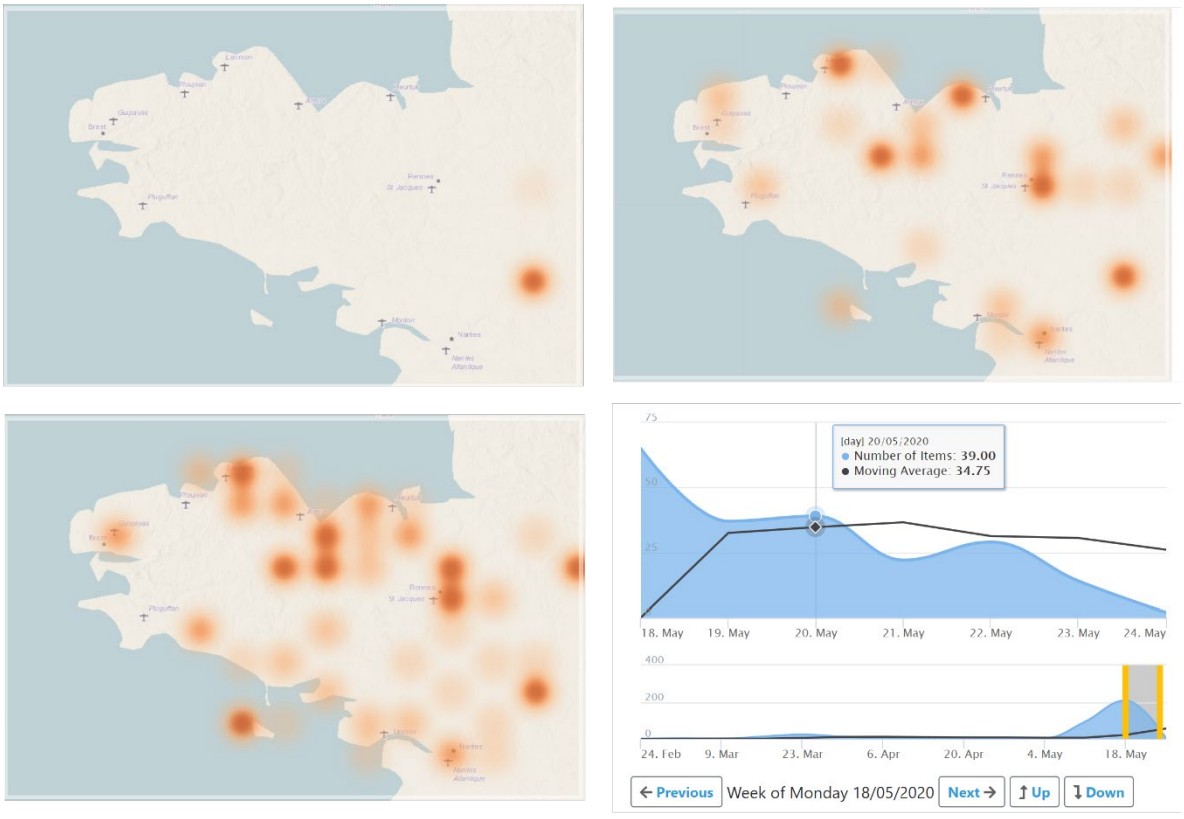
Source: EIOS system, 2020.

Figure 11. Map of locations mentioned in articles about possible cases of COVID-19 among abattoir workers in an area drawn on the map, corresponding to Brittany, France.



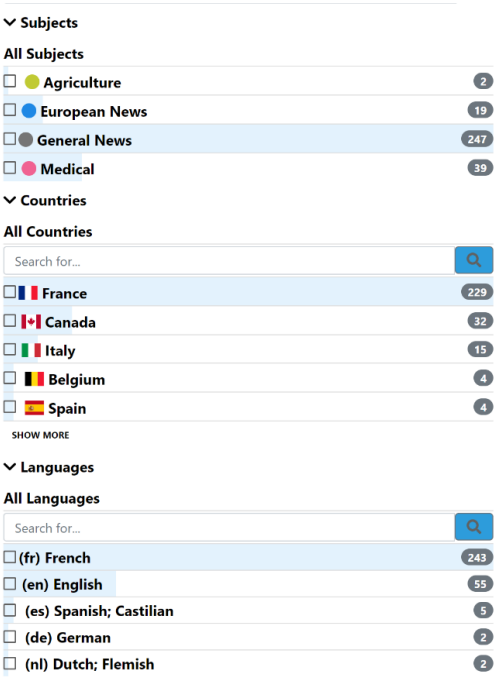
Source: EIOS system, 2020.

Figure 12. Combined interaction with visual filters (time chart and map) to investigate the development of a situation.



Source: EIOS system, 2020.

Figure 13. Frequency counts for sources covering information about abattoir-related cases in Brittany, France (May 2020).



Source: EIOS system, 2020.

4.3 Collaboration and communication features

Another key feature of the EIOS system is the possibility for analysts to exchange information about identified threats, as well as communicate across teams and institutions to share knowledge and advice.

Activities such as reading articles, saving the most relevant ones (see Figure 14) for further analysis and annotating them with comments, are all **shared across teams of the same organisation** either **through the interface** or, optionally, via **email notifications** and **daily digests**, such as the one for the GHSI network.

Figure 14. Example of a saved article within a specific monitoring and analysis scope (COVID-19 cases in Northern Italy). Other possible scopes are proposed by the system based on previous interactions.

Source: EIOS system, 2020.

This feature is meant to enable collaboration; for instance, given the large amount of information to be checked, work can be divided among members of the same team. In addition, knowing that other teams (e.g. a specific task force of experts on a given disease) have read, saved or annotated a certain article, is an indicator of the most relevant information to look at in order to have an up-to-date overview of the situation.

Users are also allowed to send specific communications, even to teams of other communities, so as to share knowledge of possible signals, or ask for advice and collaboration.

Other possible future communication tools may include immediate communication and chats to enable faster and more interactive discussion.

4.4 Future developments: handling information deluge, misinformation and disinformation

From the beginning of the COVID-19 crisis – with the announcement that a novel coronavirus had been isolated and the consequent confirmation of human-to-human transmission – the number of articles imported and made available on the EIOS system rapidly started to increase.

The total volume of articles reached a peak in March (there were more than 1 million articles in the week of Monday 16 March 2020), corresponding to the epidemic wave severely affecting Europe and North America and the generalised lockdown that ensued in many countries. In April, the system was still importing and processing an average of more than 2 articles related to the coronavirus category every second.

Such an '**infodemic**' – **an excessive amount of information** – **surrounding COVID-19,** including relevant updates as well as misinformation and disinformation, has been one of the biggest challenges for analysts around the world, including EIOS users working on COVID-19.

Based on the corresponding lessons learnt, one of the new key priorities for future developments on the EIOS system is addressing this information deluge in the following ways:

- Allow users to **better define the monitoring and analysis scope**, in particular introducing the possibility of defining a more **complex combination of filters** – for example several symptoms or public health measures mentioned in the same article AND in relation to the given disease – and establishing **new types of categories**, such as stages of epidemics (early signals, imported cases, local transmission, peak, etc.). The challenge in this case is to increase the functionality of the user interface while maintaining usability and simplicity. Another option in this regard is the **development of chat bots** or similar tools capable of **translating specific user questions into a set of filters.**
- **Group articles into stories** covering the same event, for example a specific outbreak of cases in a given facility, and the ease of lockdown in a certain country. This may be achieved by applying AI algorithms to cluster similar news articles.
- Introduce **automatic misinformation and disinformation detection** in the system, using analysis of social media information and classifiers to identify unreliable sources and individual items of disinformation. Unreliable sources will likely remain available on the portal to support specific analyses; however, the system will assign credibility scores that the user can use to further filter information to focus on credible information or on misinformation and disinformation only, depending on the task.

4.5 Future developments: guided structured rapid risk assessment

Structured and formalised risk assessment is currently missing in the EIOS system, even though some early proofs of concept are being explored by WHO.

More specifically, the objective is to introduce a form builder in the system to allow organisations and teams to define forms to guide the assessment of the specific severity, likelihood and impact of a particular public health threat, based on their own specific methodology.

As **each community and team may have its own methodology** and criteria for risk assessment, it will be important to identify a flexible solution that can not only facilitate the different needs but **enable comparative analyses and information sharing** where appropriate (e.g. if teams and/or communities have similar mandates and tasks or share jurisdiction).

In addition, as previously described, risk assessments should consider contextual information, such as specific coping capacity and infrastructure in affected areas, and reference to previous similar events.

5 Knowing more and losing less: reaction of INFORM suite to COVID-19 pandemic

The COVID-19 emergency has shown the adaptability of the INFORM suite to partner's needs and the integration of new in-coming knowledge:

- The INFORM Risk Index has been made more specific to COVID-19 and the **INFORM COVID-19 Risk Index** has been developed.
- INFORM Warning's development is in its early stages. The development of **INFORM COVID-19 Warning** ([6]) acts as an accelerated and conceptually ring-fenced case study that can contribute to the future development of a broader INFORM Warning product.
- The INFORM Severity Index can measure the severity of COVID-19 induced humanitarian crises.

5.1 INFORM COVID-19 Risk Index

When the first signs of the COVID-19 crisis became visible, the JRC adapted the INFORM Epidemic Risk Index for the COVID-19 situation and the first analyses were shared with other Commission services within the framework of the ARGUS general rapid alert system activation. These first analyses were based on the knowledge of the virus that existed at that time (February 2020), combined with the **national risk of spreading the disease and the probability of importing cases** from China, for which migration statistics and data on air travel were used.

At the end of March 2020, INFORM partners, especially humanitarian and donor organizations, requested special support for their decision-making needs in response to the COVID-19 crisis. The UN Office for the Coordination of Humanitarian Affairs (OCHA), the coordinator of INFORM and the JRC - the scientific and technical lead of INFORM - started developing a new tool based on the previously released INFORM Epidemic Risk Index (Poljanšek et al., 2018).

The results of this collaborative effort involving INFORM partners continued to evolve, and on 17 April 2020 the JRC released the INFORM COVID-19 Risk Index (Poljanšek et al., 2020), a composite indicator that identifies 'countries at risk from health and humanitarian impacts of COVID-19 that could overwhelm current national response capacity, and therefore lead to a need for additional international assistance'. The INFORM COVID-19 Risk Index has been **fully endorsed by INFORM partners** that were involved in its development.

5.2 INFORM COVID-19 Risk Index methodology and results

The INFORM Epidemic Risk Index (Poljanšek et al., 2018) is a tool for supporting early warning with additional selected and compiled contextual information about countries. It is highly relevant to the current pandemic. It was developed through an extensive process prior to COVID-19 and can be easily adapted to different scenarios. Therefore, it has been used as the starting point for a COVID-19 specific risk index, with the structure and relevant indicators retained as far as possible.

The INFORM Epidemic Risk Index consists of three dimensions: Hazard & Exposure, Vulnerability and Lack of Coping Capacity. The Person to Person component of Hazard & Exposure is the most relevant to COVID-19 and is used autonomously to focus on risk factors concerning only human-to-human transmission (Figure 15).

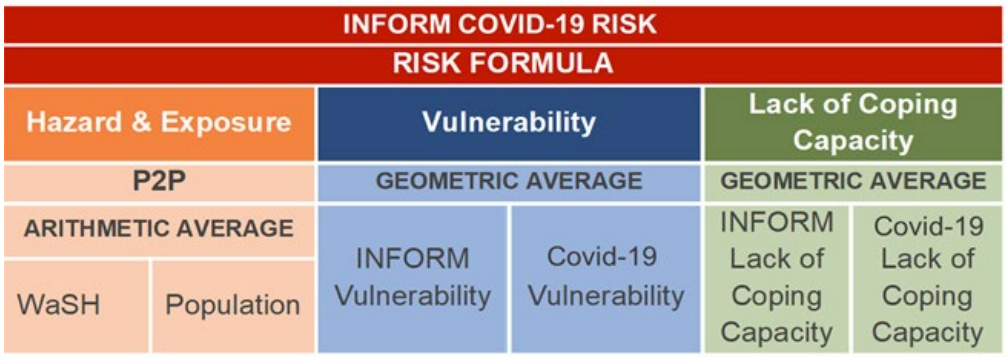
Vulnerability and Lack of Coping Capacity consist of hazard-dependent (specific to the epidemic hazard) and hazard-independent (relevant to all hazards covered by the INFORM Risk Index) aspects. Both parts are retained.

- There are many indicators or broader vulnerability and lack of coping capacity that are directly relevant to COVID-19.
- COVID-19 will compound existing risks (i.e. it will not happen alone), so broader factors of vulnerability and lack of coping capacity are important when considering the humanitarian impact of the pandemic.

The main focus of the adaptation for COVID-19 (Poljanšek et al., 2020) is the improvement of the hazard-dependent parts of the index (i.e. factors specific to COVID-19), but within the existing structure (Figure 16 and Figure 17).

([6]) https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Warning

Figure 15. The analytical framework of the INFORM COVID-19 Risk Index



Source: Poljanšek, et al., 2020.

Figure 16. Risk factors included in COVID-19 Vulnerability

Covid-19 Vulnerability	Movement (25%)	International movement
		Internal movement
	Behaviour (25%)	Awareness
		Trust
	Demographic and Comorbidities (50%)	***Proportion of the population at increased risk of severe COVID-19 disease***

Source: Poljanšek, et al., 2020.

Figure 17. Risk factors included in COVID-19 Lack of Coping Capacity

Covid-19 Lack of coping capacity	Health Capacity	***Health system capacity specific to Covid-19***	International Health Regulations Core Capacities average score
			Country Preparedness and Response Status for COVID-19

Source: Poljanšek, et al., 2020.

The COVID-19 Risk Index (like the other INFORM risk indexes) focuses on structural factors. It does not contain rapidly changing information, for example on cases, government restrictions and changing health system capacity in response to the pandemic. However, INFORM is looking at how dynamic risk information on COVID-19 can be organised and potentially aggregated for use in conjunction with the risk index.

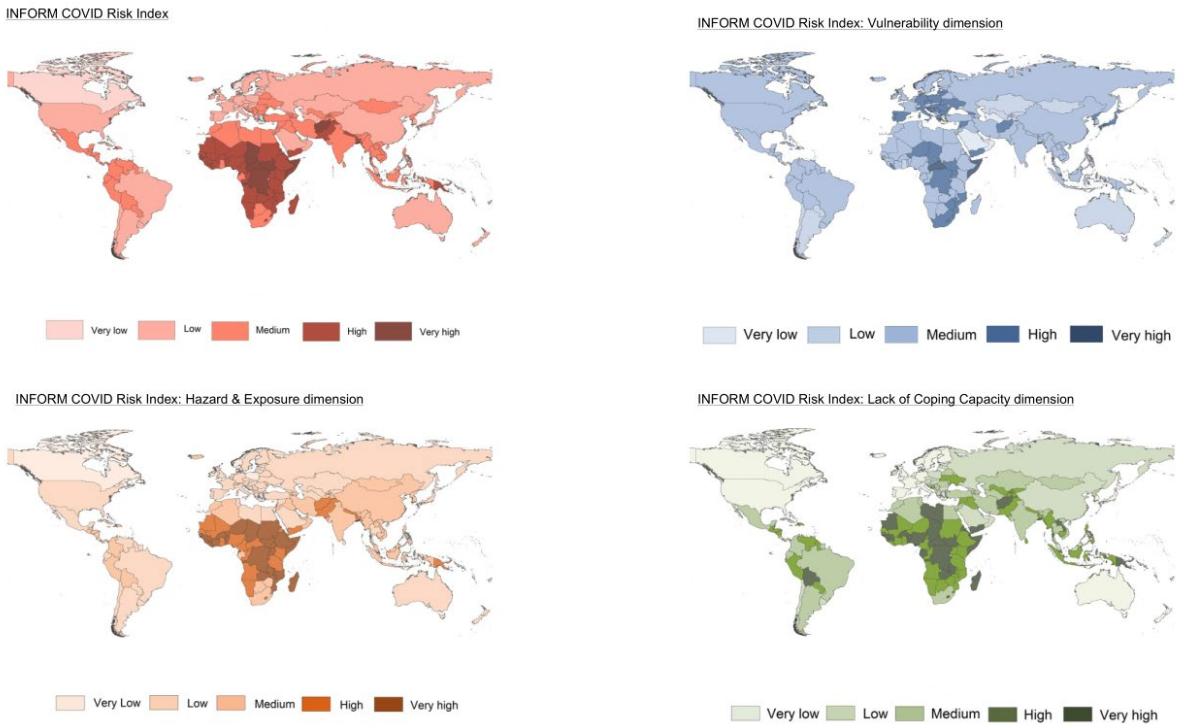
Only risk factors for which there is sufficient evidence are included.

The changes to the analytical framework are based on a literature review and expert input, and take into account (i) the most relevant and certain factors relating to COVID-19 and (ii) availability of comprehensive and quality indicators that measure the identified factors directly or by proxy.

All of the research around COVID-19 is new. Only factors for which there is sufficient published or pre-publication evidence, or that are widely accepted and publicised by credible organisations are included.

The results of INFORM COVID-19 Risk Index are summarised in Figure 18.

Figure 18. Results of INFORM COVID-19 Risk Index



Source: Poljanšek et al., 2020.

A specific analysis of the vulnerability dimension of the INFORM COVID-19 Risk Index (Figure 19) has revealed that socio-economic factors will primarily dictate the impacts of COVID-19 in lower income countries and should guide our response in regard to the world's poorest and most vulnerable. The analysis suggests that factors that make individuals vulnerable to COVID-19, such as age and specific pre-existing conditions, drive vulnerability and risk in higher income countries.

However, in countries with the highest risk of humanitarian crisis as a result of COVID-19, which are overwhelmingly low-income and lower-middle-income countries (LICs and LMICs), factors of vulnerability that are highly specific to COVID-19 are less important than broader socio-economic factors or those associated with vulnerable groups such as food insecurity, people in poor health and displaced persons.

Although this conclusion partly derives from the way the risk index is conceptualised, it suggests that – at least in the preparedness and early response phase of the pandemic in countries at high risk of a humanitarian crisis – risk can be reduced by addressing broader vulnerabilities through 'no regrets' strategies and interventions.

This is also important because impacts on humanitarian operations and the secondary impacts of the pandemic are also likely to have wide-ranging humanitarian consequences beyond the direct health impacts of the disease.

5.2.1 Impact of the INFORM COVID-19 Risk Index

The INFORM COVID-19 Risk Index has gained high visibility and has been used by many organisations in analyses and documents:

— It was mentioned as one of the forward-looking risk analyses at country level in the latest update (May 2020) of the Global Humanitarian Response Plan for COVID-19 ([7]).

— It was presented in the report '*How COVID-19 is Changing the World: a statistical perspective*' issued by the Committee for the Coordination of Statistical Activities ([8]).

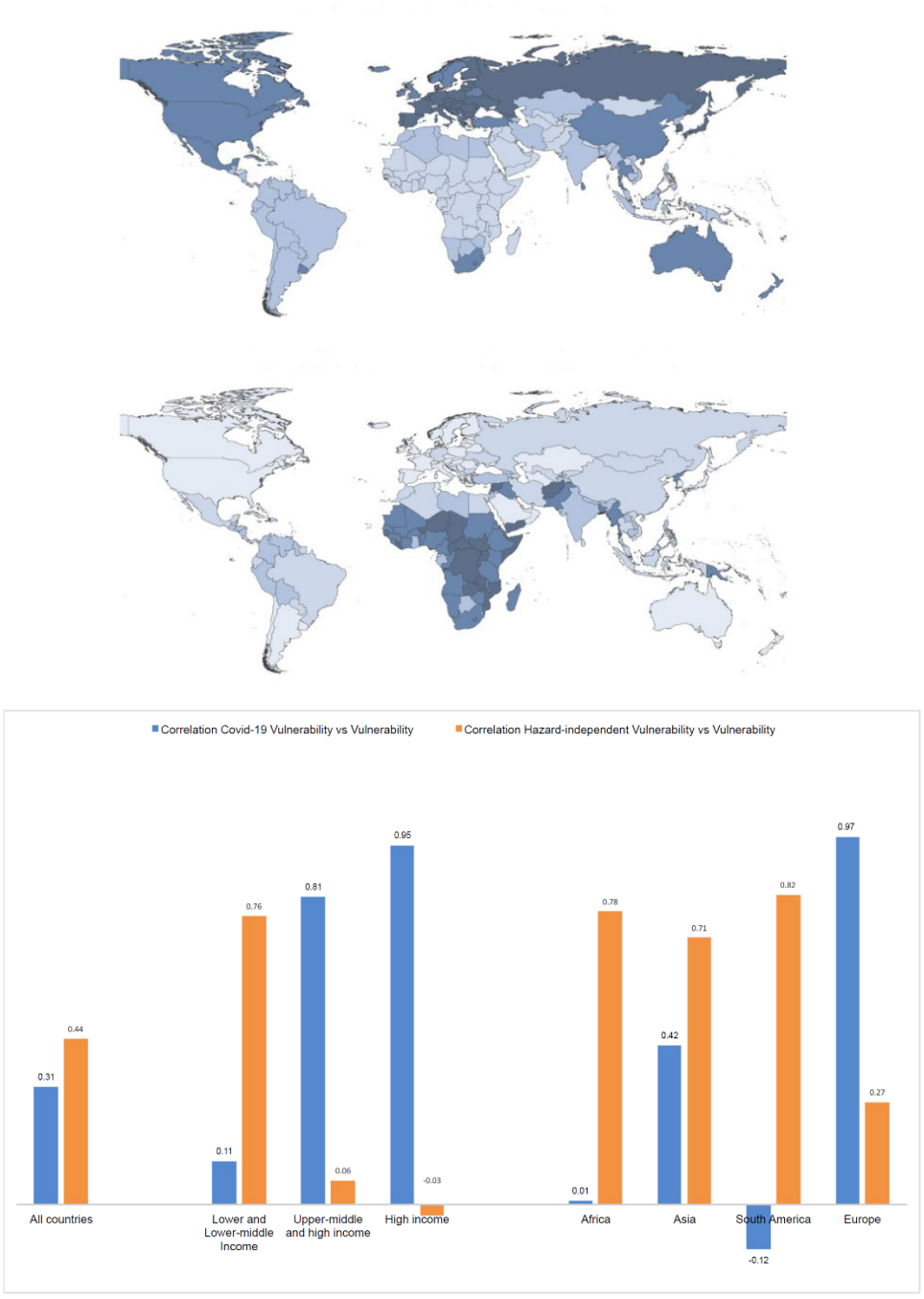
([7]) UN OCHA, *Global Humanitarian Response Plan – COVID-19*, 2020 (available at https://www.unocha.org/sites/unocha/files/Global-Humanitarian-Response-Plan-COVID-19.pdf)

([8]) Committee for the Coordination of Statistical Activities, *How COVID-19 Is Changing the World: A statistical perspective*, 2020 (available at (https://unstats.un.org/unsd/ccsa/documents/covid19-report-ccsa.pdf)

— It has been used by humanitarian organizations, such as the UN Global Food Security Cluster ([9]).

— The Internal Displacement Monitoring Centre (IDMC) used the INFORM COVID-19 Risk Index to identify areas at highest risk of coronavirus-related impacts. Its product ([10]) shows which countries/territories are most at risk from the health and humanitarian impacts of COVID-19 and is overlaid with displacement data.

Figure 19. Contribution to vulnerability by income groups and regions – in lower-income countries and lower-middle-income countries COVID-specific vulnerability factors are less important than broader vulnerability factors



Source: Poljanšek et al., 2020.

([9]) UN Global Food Security Cluster, 'TWG – COVID-19 meeting', 4 May 2020 (available at https://fscluster.org/sites/default/files/documents/2020-05-04-twg_-covid_19-meeting.pdf)

([10]) IDMC, 'Coronavirus crisis: internal displacement' (available at https://www.internal-displacement.org/crises/coronavirus#map)

Interest in the INFORM COVID-19 Risk Index is also rising within the Commission services involved in the management of the crisis in developing countries, mainly the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO), which is one of the key partners of INFORM.

The European External Action Service (EEAS) has also expressed interest in the tool and consulted the results during its regular early warning assessments as additional contextual information to complement the information provided by the Global Conflict Risk Index[11].

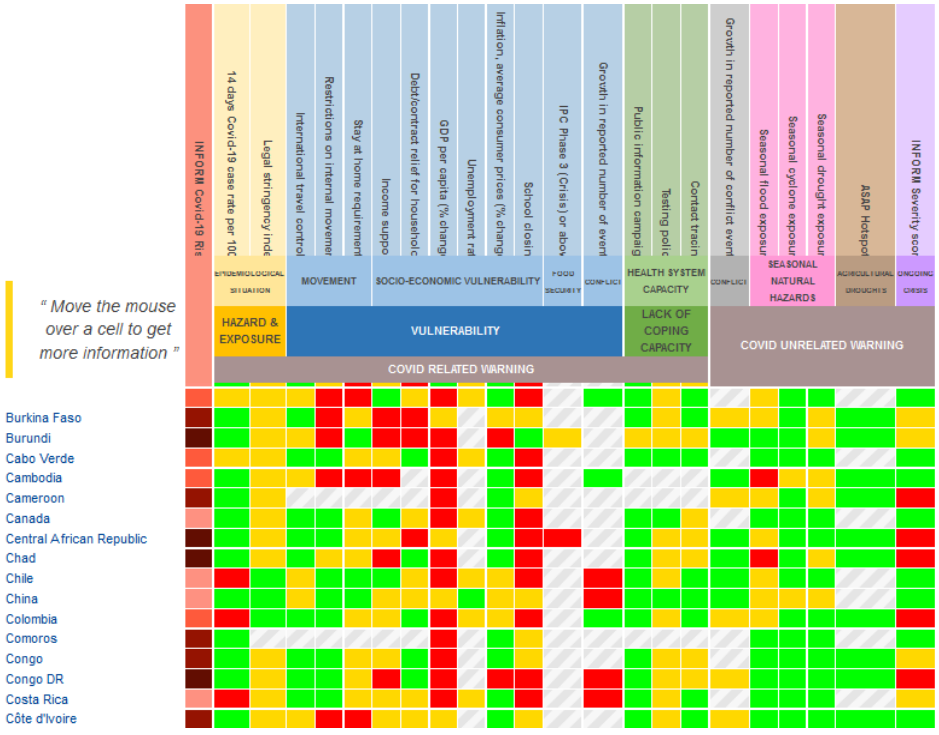
This tool was particularly useful in the very first phase of the crisis, when the COVID-19 outbreak had not yet turned into a global pandemic, and the epidemic's development in most countries was mostly unknown. The rapid evolution of the global pandemic (with extensive local community transmission eventually detected in Europe) changed the scenario, and the containment measures that the governments put in place to reduce the impact of COVID-19 changed the pre-existing risk drivers used in the model. The lockdown dramatically reduced the movement of people and the probability of contact.

5.3 INFORM COVID-19 Warning

In collaboration with UN OCHA, the JRC is developing a tool that can help identify, monitor and anticipate where COVID-19 could compound existing risks to cause new or exacerbate existing humanitarian crises. INFORM COVID-19 Warning (Figure 20) aims to provide analyses that can be used to support decisions on preparedness and anticipatory action to mitigate the direct and indirect humanitarian impacts of the COVID-19 pandemic.

The purpose is to provide a more dynamic and up-to-date picture of how the pandemic is evolving and how it interacts with other hazards, vulnerabilities and coping capacities to affect crisis risk. Within this context, the EIOS system, with all of its existing and evolving features, can be enhanced by and significantly contribute (as a possible data source) to INFORM Warning.

Figure 20. The INFORM COVID-19 Warning (beta version) dashboard provides a global overview of the warning status of the selected risk factors



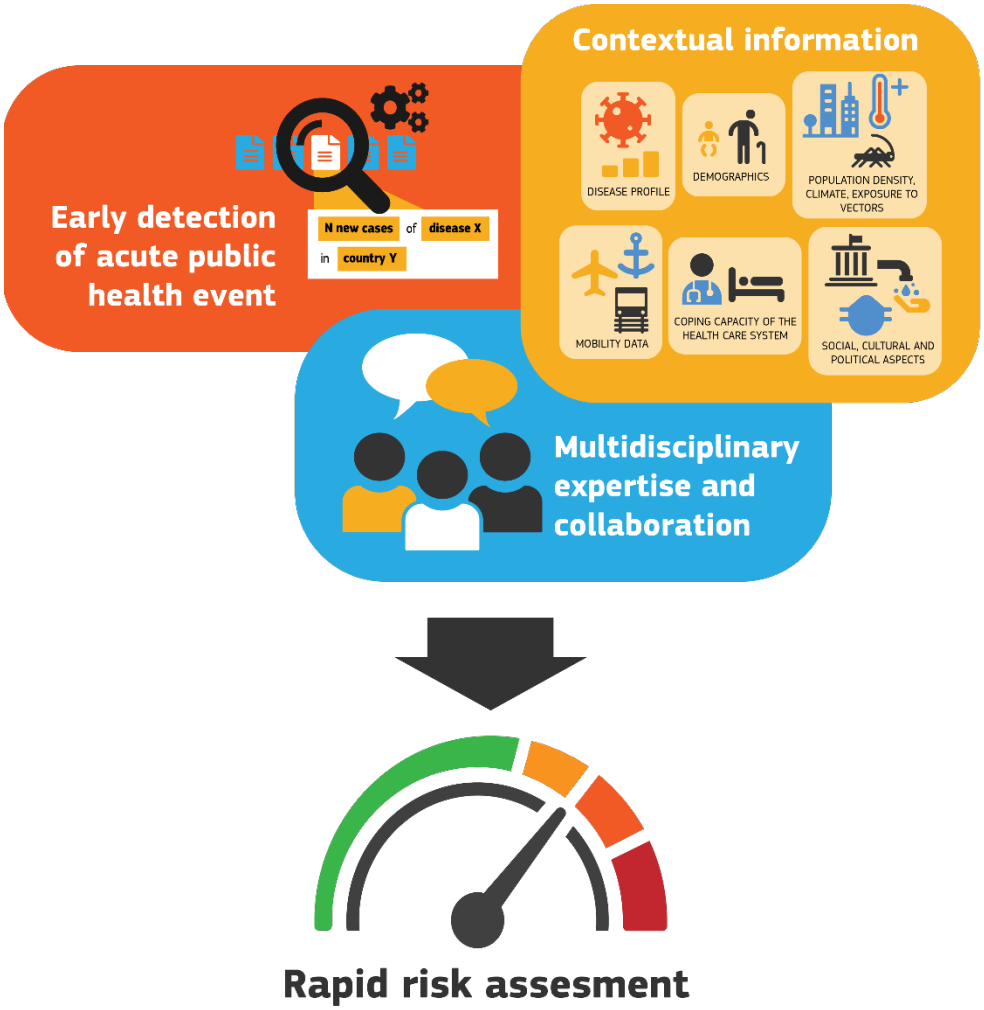
Source: JRC, INFORM, 2020.

(11) https://ec.europa.eu/knowledge4policy/dataset/ds00151_en

6 From the early warning system to the rapid risk assessment

6.1 The need for contextual information to support rapid risk assessment

Figure 21. The required elements for performing rapid risk assessment



Source: JRC, 2020.

As previously discussed, the early detection and identification of potential public health threats is only the first step in the public health intelligence function. Once they are detected and identified, it is particularly important to assess the corresponding level of risk, so that any subsequent action, if required, is both adequate and proportionate.

As illustrated in Figure 21, to support an informed rapid risk assessment, a system such as that being developed for the EIOS initiative should provide experts with the information they need to **facilitate an assessment of the hazard, the exposure and the context in which acute public health events do occur or could occur** (World Health Organization, 2012).

Possible aspects that such informative content should cover are (Mantero and Doherty, 2017):

— **agent and disease components**, including characterization (how the disease is transmitted, the pathogen's virulence, existing options for response and mitigation measures, etc.), epidemiological profile (how far the disease has spread worldwide and in the specific areas affected by outbreaks) and expertise available (researchers, clinicians treating the disease);

— **host components**, including the population's demographic profile and health status, as well as (for the human population) relevant social and cultural aspects;

— **additional contextual components**, including coping capacity of the health care system in the affected country or sub-national area, exposure to potential vectors (e.g. insects or other wild animals for certain communicable diseases), climate and geographical profile, and relevant economic and other sociopolitical aspects (presence of conflicts, governance, etc.).

6.2 INFORM tools as contextual information

In addition to the aforementioned qualitative and quantitative information, analysts performing rapid risk assessment could be provided with **risk indices that summarise the profile of a given country or area**, in general or with respect to a specific disease or type of threat (e.g. respiratory diseases, vector-borne diseases, food-related diseases, CBRN threats). These indices may therefore help the analyst to point out which particular aspects are more problematic and where more attention should be directed.

In particular, as already discussed, the **INFORM Epidemic Risk index**, the **INFORM COVID-19 Risk Index** and **INFORM Risk Index** provide relevant components to highlight relevant risk factors concerning exposure, vulnerability and coping capacity to epidemics and disasters in general.

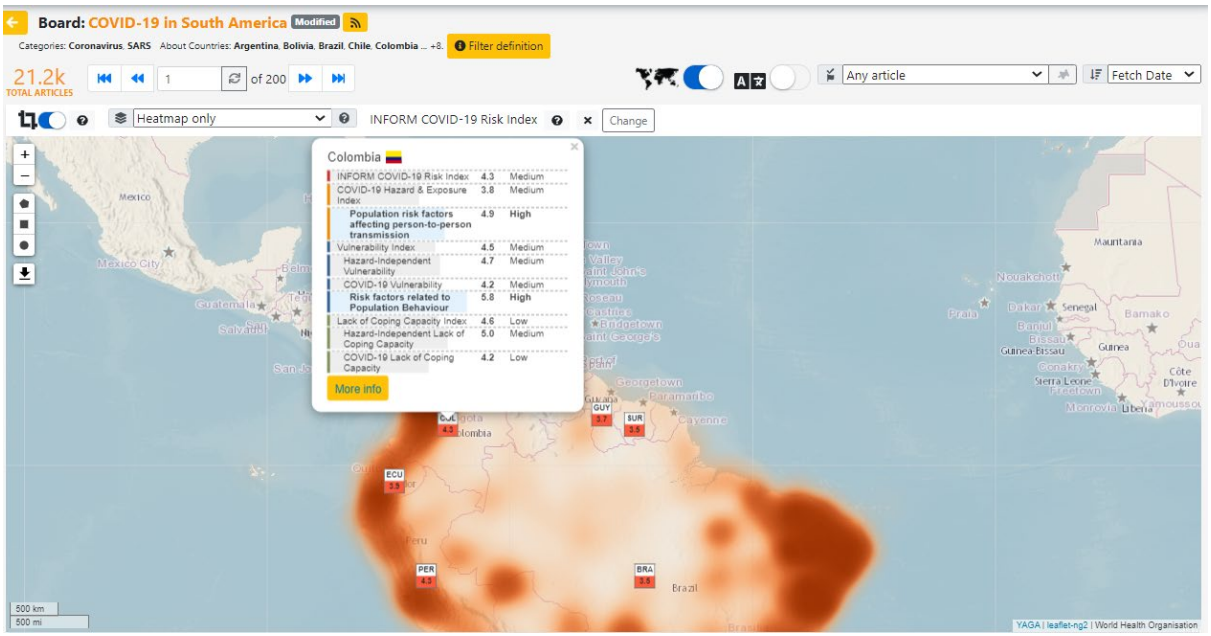
6.3 Early integration of INFORM tools into the EIOS system

6.3.1 INFORM country preview

In Figure 22, a heat map of the distribution of countries mentioned in the context of COVID-19 cases in the northern part of South America is shown. With respect to the visualisation already discussed in paragraph 4.2.3, **contextual information** is also shown, namely the **INFORM COVID-19 Risk Index** for countries within the shown geographical extent shown.

Each icon indicates a country, with a value (0-10 scale) indicating the overall risk of humanitarian crises, which is also represented by lighter or darker (more at risk) shades.

Figure 22. INFORM Risk Index displayed on a map along with the distribution of mentioned locations, in the context of COVID-19 in South America. For each country, a preview of the most relevant/critical risk factors is shown when clicking on the map marker.



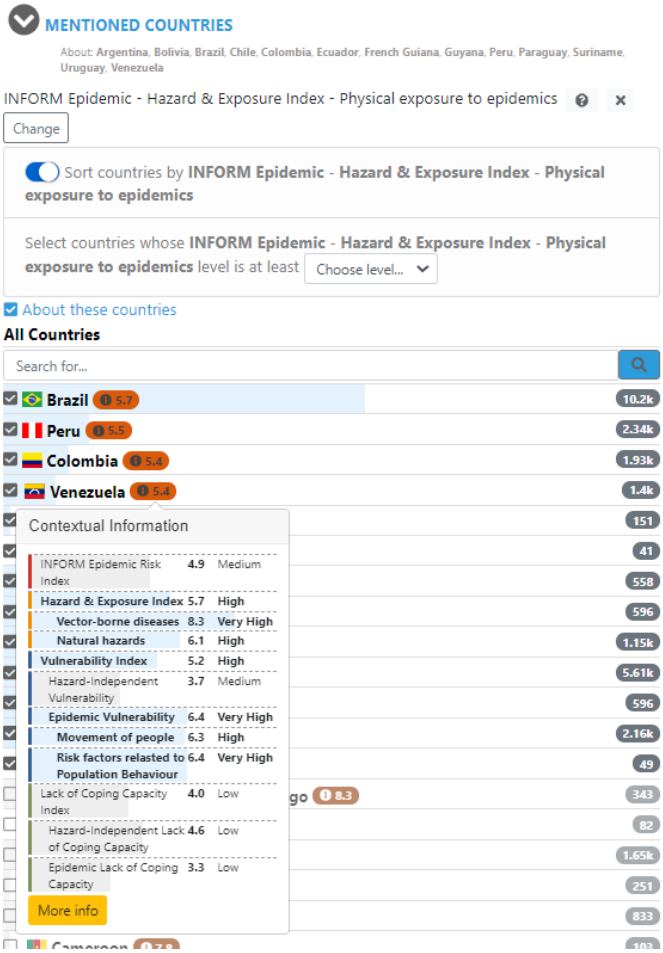
Source: EIOS system, 2020.

Moreover, by clicking on the icons, users can display a pop-up window with a preview of the most relevant indices of the selected INFORM tool, that is those covering hazard and exposure, epidemics exposure, lack of coping capacity and vulnerability. In addition, the most critical aspects (relevant indices with high or very high values) are also highlighted; for instance Colombia (as shown in Figure 22) is mainly exposed to population risk

factors affecting human-to-human transmission of COVID-19, and is also vulnerable to risk factors related to population behaviour.

This **preview** allows analysts to have an **at-a-glance understanding of the most critical risk factors** for any given country. The same preview is shown beside the list of mentioned countries used to filter articles (see epidemics exposure index in Figure 23). Analysts could use the risk level provided for the countries to **prioritize their monitoring and analysis**, e.g. focusing on the most vulnerable countries for specific components only.

Figure 23 INFORM metrics (e.g. physical exposure to epidemics) are optionally shown also in the list of mentioned countries that analysts can use to define the scope of monitoring and analysis. In this specific case, mentioned countries are also sorted by the INFORM score rather than by the number of articles



Source: EIOS system, 2020.

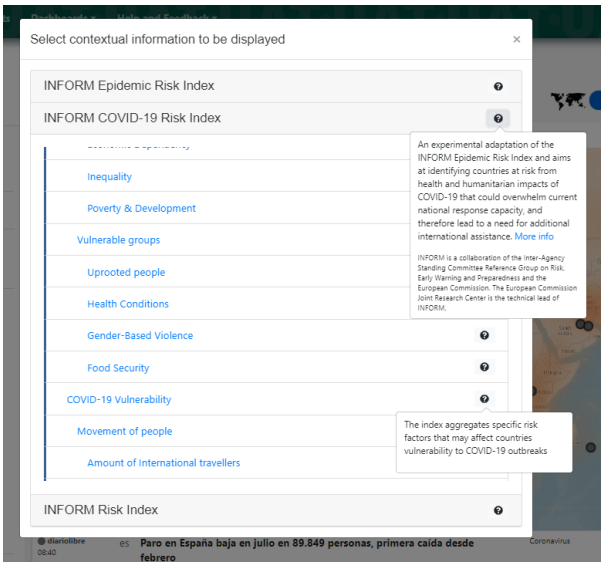
6.3.2 Selection of INFORM indices

By clicking on the button select or change contextual information (located just above the map and close the mentioned countries filter), a modal window appears where the user can choose to visualise different index components and learn about their purpose and meaning (see Figure 24).

6.3.3 Contextual information legend

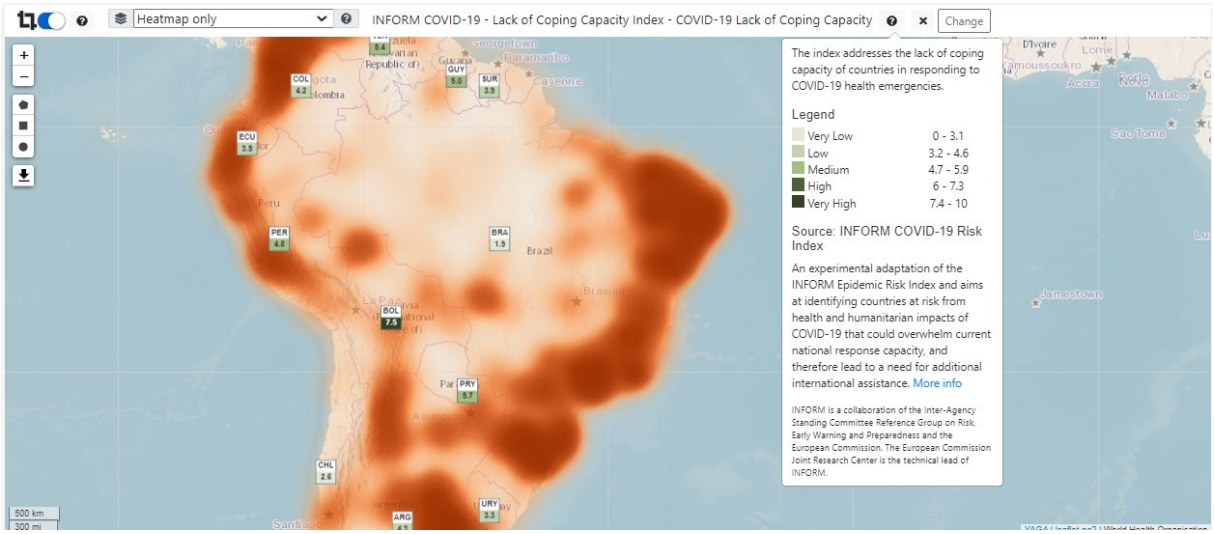
To provide a better understanding of the selected contextual information, a legend is displayed, including an explanation about the metric and further reference (see Figure 25).

Figure 24. List of available contextual information options, including INFORM indices. Explanation is provided to clarify the scope and meaning of certain metrics.



Source: EIOS system, 2020.

Figure 25. Map of INFORM COVID-19 Lack of coping capacity index for southern American countries, along with the corresponding legend.



Source: EIOS system,, 2020.

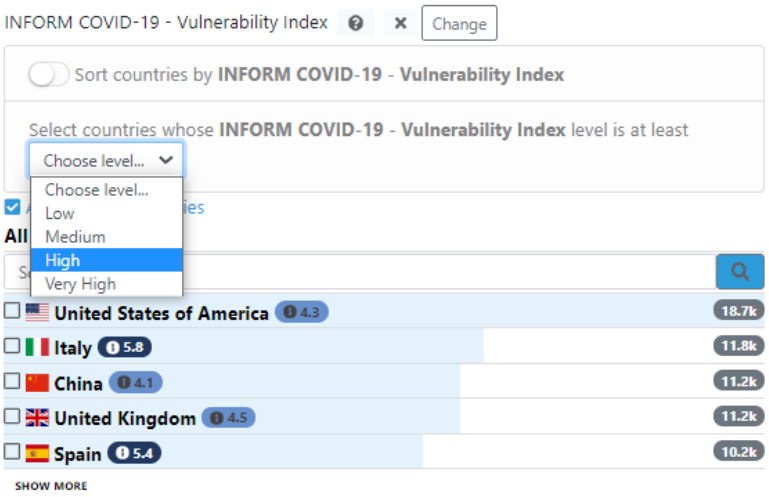
6.3.4 Sorting and filtering mentioned countries by INFORM metrics

In the filter section, countries are, by default, sorted by the number of articles they are mentioned in (to highlight those that have more mentions in the given context). They can also be **sorted by ranking according to the selected INFORM index** (see Figure 23).

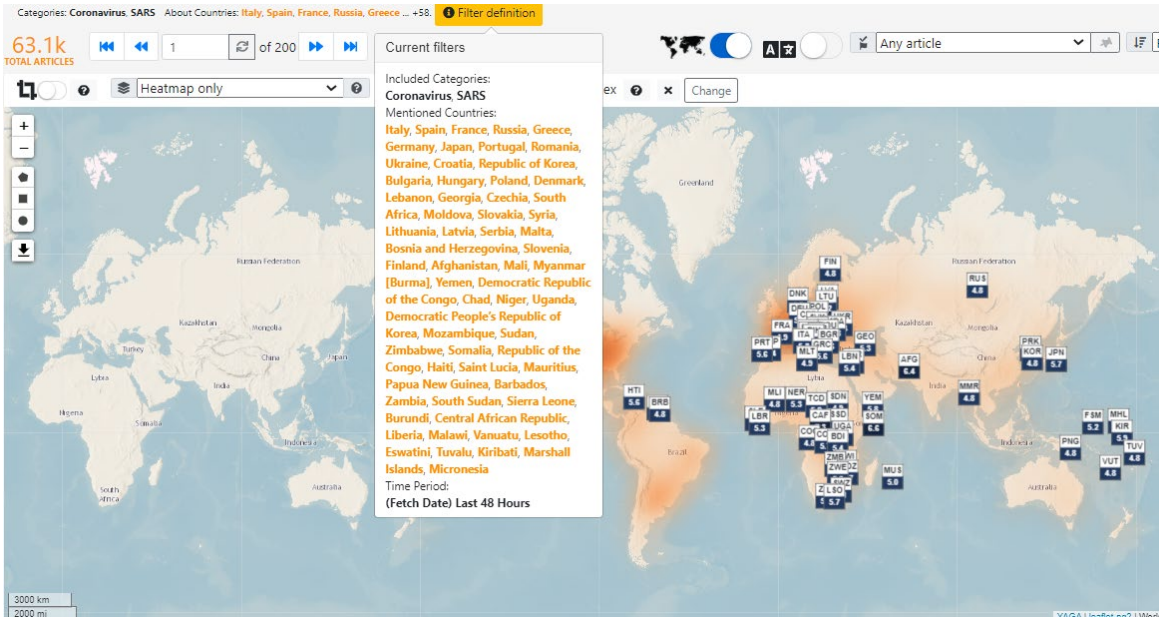
INFORM metrics can also be used as **filters to define the monitoring and analysis scope**, for example to focus the surveillance on countries with higher risk (see Figure 26).

Figure 26. Filtering by INFORM metrics: in the specific case, the selected mentioned countries are those that have at least a high score level for the INFORM COVID-19 Vulnerability index (a). The specific result, along with the modified monitoring and analysis scope is displayed on the map (b).

(a)



(b)



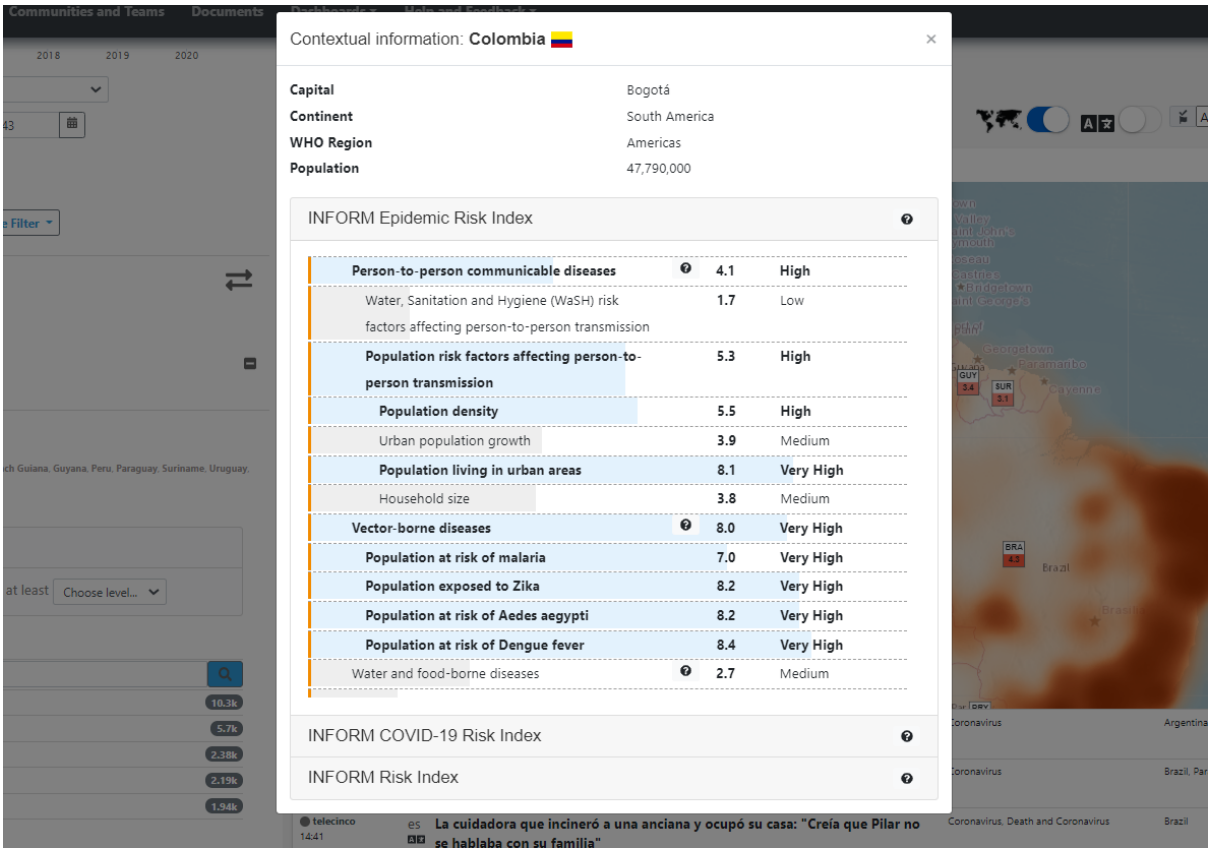
Source: EIOS system, 2020.

6.3.5 Detailed country profiles

The **underlying components** of the main INFORM indices can be further investigated by looking at the **country profile** (Figure 27).

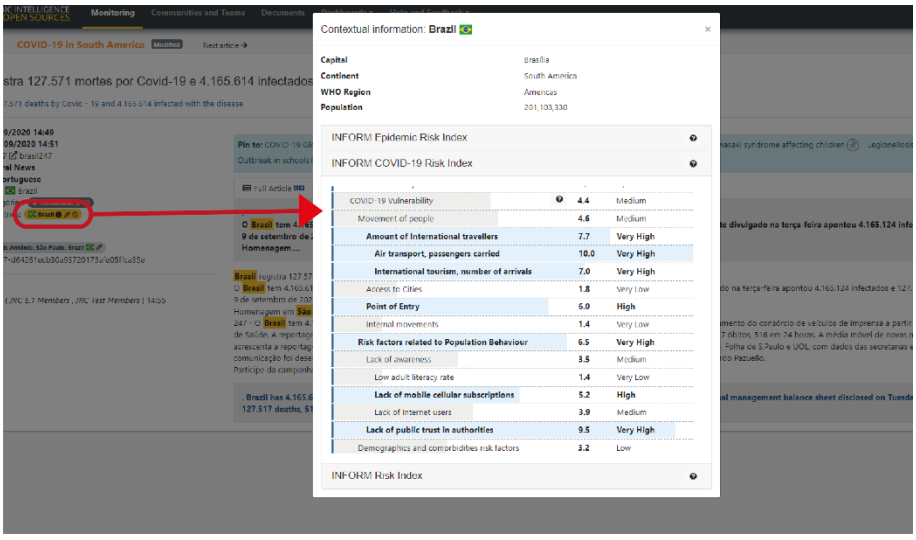
This can be accessed by clicking on 'More info' in the preview (Figure 22 and Figure 23) or by clicking on the 'Info' icon beside the mentioned country, in the preview and details of each article (Figure 28).

Figure 27. Country profile with INFORM indices. Horizontal bars add a rapid visual and relative representation of the scores.



Source: EIOS system, 2020.

Figure 28. Navigating from the detail of an article mentioning a specific country (e.g. Brazil), to the corresponding country profile.



Source: EIOS system, 2020.

6.3.6 Future developments

Besides the update of existing metrics, future developments of the INFORM integration in the EIOS system will include the **incorporation of sub-national profiles** for specific areas at risk.

Moreover, the **underlying indicators** used for each index could also be included and complemented with others available (Lorenzo Ortega and Doherty, 2018) as well as information about previous events. This would allow analysts to drill down to the most critical aspects to be further considered in the specific situation to be assessed.

Furthermore, future specific future versions of the **INFORM tools and metrics**, possibly tailored to a given type of disease (e.g. COVID-19 and similar respiratory diseases, Ebola) could be incorporated in the system and suggested to the analysts when they are considering a context of analysis involving that specific disease.

7 Conclusions and way forward

7.1 Beyond the COVID-19 crisis: lessons learnt

The COVID-19 pandemic has proven, beyond any doubt, that early detection is a key factor in reducing the impact of public health risk as it triggers earlier preparedness and response actions. As in any crisis situation, there are key lessons to learn from this pandemic that should guide our future development priorities. Some of these are presented below.

7.1.1 Early detection should be as early as possible, on a global scale

From the COVID-19 crisis we clearly learnt how communicable diseases, such as respiratory pathogens with certain characteristics, can spread much further and faster than ever before because of globalisation.

At the beginning of the crisis, the focus of early detection was on the risk of importing new cases from China or other countries where local transmission had already been identified. In fact, the general assumption was that the virus was not yet circulating in other regions of the world, including Europe.

In reality, some studies seem to show that undetected local transmission could have been ongoing for weeks in Europe even before the outbreak in Wuhan was officially announced, in particular, the SARS-CoV-2 virus was retrospectively identified in a swab collected in December 2019 from a patient who was hospitalised for pneumonia in Paris, France, and who had no epidemiological links with China (Deslandes et al., 2020). In addition, traces of the virus were detected in wastewater samples collected in Milan and Turin, Italy, in December 2019 (La Rosa et al., 2020).

For certain emerging priority diseases, such as those caused by respiratory pathogens, the EIOS system should therefore be improved so that it can **capture potential early signals** (e.g. anomalous peaks of cases requiring hospitalisation reported by media) and **suggest to experts a possible link with existing outbreaks**, even if these are identified elsewhere in the world. Further investigation on these anomalies may help **anticipating the detection of the disease in other regions**.

7.1.2 Early detection must trigger early action

Detecting a public health threat as early as possible is only useful **if this is rapidly followed by appropriate actions** by international, national and/or local authorities, in terms of:

- response where the threat is detected, for example specific containment measures and international support;
- prevention and preparedness in other countries or areas in which the threat is still undetected, for example increased production and stockpiling of personal protective equipment for medical staff and the general public, reorganisation of the health care system, preparation of testing kits (and related material), and initial screening of potentially affected people.

The COVID-19 crisis has shown that any delay in carrying out these actions can have dramatic consequences, to the point that extreme measures such as generalised lockdowns may subsequently become the only viable options.

Evidence-based risk communication is needed to allow fast and adapted decision making. The EIOS initiative has the potential to play a key role in achieving this, especially if its expansion to include other stakeholders and further development of tools and knowledge (e.g. contextual information for informed risk assessment) continue.

The involvement of an increased number of national organisations and communities of practice, combined with increased public health risk awareness, can help decision makers in building trust and confidence in the results of experts' analyses.

7.1.3 Every disease can have different impacts and consequences: think and act beyond COVID-19

Before COVID-19, other epidemics such as Ebola, Zika, MERS, SARS and different types of influenza made the headlines over the past two decades. Despite some similarities, each of these diseases had a different impact and spread.

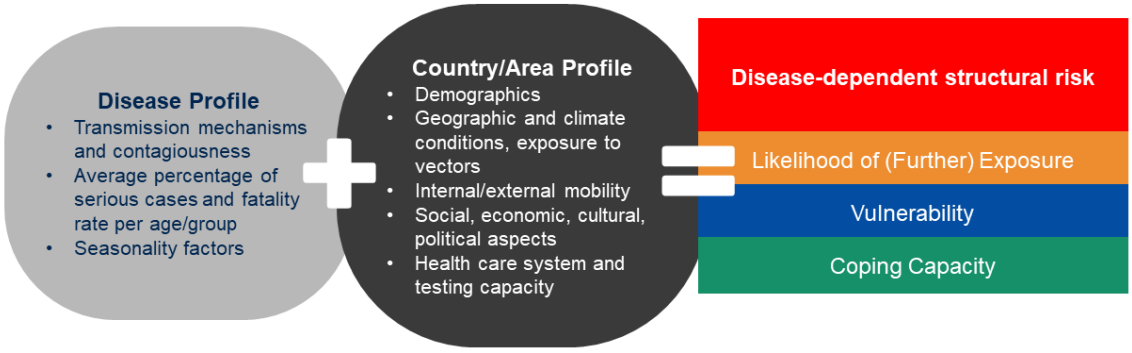
Ebola, for instance, has a much higher fatality rate than COVID-19, yet the outbreak was confined to certain areas of Africa (apart from exported cases and very limited transmission), and the number of reported deaths over the past decade is less than that officially reported by countries such as Spain or Italy in just 3 months of the COVID-19 outbreak. Although Ebola had devastating consequences for the countries involved, COVID-19 continues to have global direct and indirect impacts on all countries around the world, irrespective of the number of cases reported (e.g. cooperation programmes have been affected by delays and disruptions, general vaccination campaigns, employment and mental health have been affected by social measures, health-care systems have been overwhelmed with COVID-19 cases, which has affected capacity to address other health conditions, etc.).

If we consider the complexity of all of these aspects, we can conclude that the risk posed by COVID-19 cannot be assessed through the same lens and criteria as used for Ebola. Analogously, the risk posed by other future outbreaks caused by other pathogens should be evaluated in the scope of a **broader and more flexible framework** that allows experts to tailor it to the specific features of the disease or threat.

The specific disease profile (in terms of modes of transmission, morbidity by age and other demographic features, seasonality and geographical factors, etc.) **should be subsequently matched with the profile of potentially affected areas** to better estimate their exposure, vulnerability and coping capacity (Figure 29).

The EIOS system, combined with the INFORM approach to risk assessment (and eventually the planned WHO initiative for a federated knowledge graph) can be effectively used to assess different types of diseases.

Figure 29. The challenge of assessing the specific structural risk of epidemics – matching disease and country/area profiles



Source: JRC, 2020.

The EIOS system already brings together multi-disciplinary expertise to monitor a very wide spectrum of human, animal and plant diseases, including potentially new diseases not yet known to us, as was the case for the novel coronavirus disease at the very beginning of what later became the COVID-19 pandemic. INFORM is conceived to be easily adaptable to different disease profiles, by combining different specific indicators and/or adjusting the weight assigned to them. It therefore makes sense to bring the two together as the first step towards creating a powerful support tool for contextual rapid risk assessment of emerging and re-emerging diseases.

7.1.4 Rapid risk assessment should be oriented towards decision-making support

As a consequence of the lessons learnt discussed above, early warning and rapid risk assessment should explicitly provide support to decision-making; in other words, the concept of risk handled by the tool should be specifically tailored to the scope of the preparedness and response measures that could or should be taken in the specific scenario.

As the COVID-19 crisis has shown, every country can be potentially exposed and extremely vulnerable. Even the wealthiest countries, which normally have stronger coping capacity, may suffer from a strong impact and therefore be called to adapt their systems and rapidly adopt extreme measures.

Supporting contextual knowledge for rapid risk assessment should therefore inform decision-making regarding the **specific containment measures that may be needed in a given scenario**, how they can be effectively implemented, the expected impact (both on the epidemic and on society / the economy) and how the outcomes

can be evaluated afterwards. Continuous monitoring of the effect of the measures implemented and the public's reactions should also feed back into the process, to ensure that the response remains relevant and appropriate and to inform risk communication and citizen engagement efforts.

7.1.5 Infodemics could also affect science

Since the beginning of the COVID-19 pandemics, an unprecedented amount of scientific contributions of varying quality has been made publicly available worldwide. Although some articles went through an unusually fast peer-review process, many others have been published just as preprints, that is, without being previously validated by the scientific community.

Currently, the two most popular repositories of preprints covering coronavirus research are bioRxiv ([12]) and medRxiv ([13]). Such repositories allow researchers to quickly disseminate their results, and rapidly inform the scientific community and, eventually, policy makers.

As an advantage, the availability of preprints can allow fundamental research data on a novel disease to be shared quickly, thus contributing to the definition of evidence-driven policies to better face an emergency. For instance, data from different studies can be aggregated to develop early warning models using AI algorithms, and/or become an additional source of contextual information for rapid risk assessment.

However, as preprints are only assessed for plagiarism and incompleteness, the lack of a proper peer-review process comes with a caveat. In fact, in both repositories, the following disclaimer is shown 'Preprints should not be relied on to guide clinical practice or health-related behaviour and should not be reported in news media as established information'.

Even the most accurate model, if feed with low-quality data may lead to misleading results, which may in turn negatively influence decision making. For this reason, preprints should be at least informally addressed by the wider scientific community, to determine the robustness and reliability of the data before they are used.

By analogy with the monitoring and verification process driving public health intelligence in the EIOS system, a similar approach could be adopted to determine the quality of rapidly disseminated scientific results. Preprints could be evaluated using AI algorithms, and if they pass the first check, they could be submitted to experts for further analysis and validation.

7.2 Key priorities for the EIOS system

For the EIOS system, a number of priorities can be identified along the three lines of action discussed in the sections that follow. These primary issues are consistent with those that were raised by stakeholders in the EIOS Global Technical Meetings held in Geneva (2018) and Seoul (2019).

The developments envisaged will be carried out in the framework of existing and future agreements between the JRC, the WHO and other EIOS stakeholders and collaborators, including external partners such as universities and research institutes.

7.2.1 Improving early detection and early warning

Early detection can be improved by incorporating even more potentially relevant information, and by increasing the ability of the system to automatically extract knowledge from the information and therefore highlight potential sources of threats.

Along these lines, priorities include the following:

- Monitor **social media** (dashboard with information from Twitter and incorporation of this information in the EIOS system), including automated sentiment analysis
- Monitor **misinformation** (installation of tools already developed by the JRC and subsequent integration in the EIOS system) to cope with 'infodemics'

([12]) https://www.biorxiv.org/
([13]) https://www.medrxiv.org/

— Include of further **metadata provided by EMM/MEDISYS** ([14]): clusters (i.e. grouping articles into stories), event metadata, entities (e.g. specific people or organisations mentioned in the articles), quotations, and an improved geolocation algorithm; quotes can be extracted automatically and linked to entities. Other advanced algorithms could be explored to improve the automatic extraction of meaning from articles.

— Introduce **additional advanced filtering capabilities** in the user interface to better define the monitoring and analysis scope and deal with increasing amounts of information.

— Develop **anomaly detection algorithms** based on the volume of information on a given topic (e.g. sudden increase in news about a given disease in a given country); a statistical analysis of the volume of information is available from EMM/MEDISYS. It is however important to stress that an increase in information in the news may not necessarily be relevant to public health, but rather may be based on what the media perceives to be of interest to its readership. Thus, it is important to define which anomalies should be captured with specific filters (see previous point).

In addition to the previous proposals, other solutions to enhance early warning could be explored, based on alternative sources of information (such speech-to-text recognition from radio stations) and models.

With regard to the latter, an alternative approach at least for certain diseases could be the employment of 'omic technologies' (see for instance Schneider and Orchard, 2011) and genomics in particular. The analysis of mutations in full genomic viral sequences – published online in databases such as GISAID ([15]) – could be employed to perform 'genomic surveillance', that is, monitoring the temporal and spatial distribution of specific mutations associated with increased virulence and infectivity and therefore having a selective advantage. This could be particularly helpful for viruses that have a relatively low sequence mutation rate, such as SARS-CoV-2 (Romano et al., 2020), and coronaviruses in general (Denison et al., 2011).

7.2.2 Enhancing collaboration and knowledge management

A priority for the EIOS system is enhancing communication and knowledge sharing among communities of practices collaborating on the EIOS platform, with specific tools for reporting and collaborative monitoring and risk assessment.

Another priority is continuing the integration of contextual information to facilitate rapid risk assessments and build specific analytics tools that are able to extract knowledge from these indicators.

Possible development actions include the following:

— Integrate and develop **taxonomies and ontologies in the health domain** (diseases, symptoms, etc.). Such knowledge can serve as both a form of contextual information and additional input for AI algorithms to improve automatic early detection and analysis.

— Using the existing INFORM database as a start, further develop and Incorporate a **library of vulnerability and coping capacity indicators**, that includes detailed demographic profiles of the country and specific sub-national, comorbidity index, connectivity and traffic, and mobility and migration data, number of hospital beds and intensive care units.

— Integrate other databases including **information about past events**, namely data about past outbreaks (epidemic curves and trends in fatalities, hospitalisation, etc.), the **specific containment measures adopted** to address them (including the need for international aid) and the related impacts. Specific Information regarding the different contingency plans could also be extracted via media monitoring to help analysts understand what has been successful or not in the management of the crisis. This is a necessary step for the development of **analytics and predictive capacities to support crisis monitoring and management**, addressing the development of the disease in similar scenarios (e.g. countries with comparable profiles and situation), including with the support of AI algorithms.

— The **application of AI analysis to previous evaluations of similar threats carried out by analysts** on the platform will allow to patterns in diseases to be identified, providing an initial, automatic assessment of potential impacts and the evolution in time and space of the disease.

([14]) https://medisys.newsbrief.eu/
([15]) https://www.gisaid.org/

7.2.3 Expansion to include other stakeholders

The EIOS initiative aims at to expand to include other institutions and communities, such as more WHO member states, non-governmental organisations and networks of public health practitioners.

Beside the need for better supporting collaboration, this long-term strategy poses challenges, including in terms of the technical capacity of the system, with a constant need to monitor and revise the effectiveness of its software architecture.

7.3 Future cross-fertilisation between the EIOS system and INFORM

INFORM and the EIOS system are the result of partnership collaboration. They are reliable, sustainable and credible tools.

Partners are not only the users of the tools but also the data providers, knowledge feeders and above all the stakeholders of the platform. They are the engine of continuous feedback, improvement and adaption to specific requirements.

The COVID-19 emergency has shown the **flexibility of both tools in adjusting to new emergent risk** and the quick integration of new knowledge and information.

The aim of further cross-fertilization of the EIOS system and the INFORM suite is to **cover the whole disaster risk management cycle**. This would be the core of the sustainable risk management capacity development which would boost every aspect of our resilience.

The integration of the INFORM suite and EIOS system is planned to be carried out in many steps to provide evidences for decision making in different phases of disaster risk management and to assure timely intervention throughout the pre-crisis time and crisis evolution.

The disaster risk managent cycle starts with the usage of INFORM Risk Index and INFORM Epidemic Risk Index to identify priorities for prevention, preparedness and surveillance. Efforts can focus on countries that emerge as being more at risk from a multi-hazard or hazard-specific perspective through an analysis of the structural risk factors. These two tools are still of major importance when the information on the actual crisis are still scarce.

During the early warning phase, INFORM Warning and the EIOS toll would allow to identify and follow any changes in risk factors, the information on first manifestation of risk, and how the impact is starting to escalate in different sectors. This would provide enough evidence for reliable a rapid risk assessment with a strong risk identification part.

During an emergency, the INFORM Severity index could provide continuous and consistent measure of the severity in time and place. Eventually, combining the output of the INFORM Severity Index ad that of the EIOS system, the consequences of response measures can be directly observed. Based on the information gathered, these measures could be adjusted to achieve optimal effectiveness.

The rescaling capacity of both tools promotes thetr usage atdifferent spatial levels, from local, subnational, national, and regional, to global. **Assuring the same governance approach within each level** would facilitate efficient protocols for coordination from local level to global level and vice versa. It would also boost the advantages of decentralised risk management, such as more inclusiveness, more successful identification of people's needs, bottom-up planning and empowerment of the local population, without losing the power of the structures at the top.

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List of abbreviations and definitions

AI	Artificial intelligence
ARGUS	The general rapid alert system of the European Commission, linking all the specialised systems for emergencies
bioRxiv	The Preprint Server for the Biology
CBRN	Chemical, biological, radiological and nuclear
COVID-19	Coronavirus disease 2019
DG	Directorate General
DRMKC	Disaster Risk Management Knowledge Centre
DRR	Disaster Risk Reduction
EAR	Early Alerting and Reporting system
EBS	Event-based surveillance
EC	European Commission
ECDC	European Centre for Disease Prevention and Control
ECHO	Directorate-General for European Civil Protection and Humanitarian Aid Operations, European Commission
EEAS	European External Action Service
EIOS	Epidemic Intelligence from Open Sources
EU	European Union
EMM	European Media Monitor
FIFA	Fédération Internationale de Football Association
GHS	Global Human Settlement
GHSI	Global Health Security Initiative
GISAID	Global Initiative on Sharing All Influenza Data
GPHIN	Global Public Health Intelligence Network
HDRAS	Hazard Detection and Risk Assessment System
IDMC	Internal Displacement Monitoring Centre
Infodemic	The excessive amount of Information (both accurate and inaccurate) about health related issues
INFORM	INdex FOr Risk Management
IT	Information technology
JRC	Joint Research Centre
LIC	Low Income Country
LMIC	Low-Middle Income Country
MEDISYS	Medical Information System
MERS	Middle East respiratory syndrome
medRxiv	The Preprint Server for the Health Sciences
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OIE	World Organization for Animal Health
Omics	Informal reference to branches of various disciplines in biology, whose names end in the suffix -omics, such as genomics, proteomics, metabolomics, and glycomics.

P2P	Person to person
SARS	Severe acute respiratory syndrome
SARS-CoV-2	Severe Acute Respiratory Syndrome CoronaVirus 2
UN	United Nations
WaSH	Water, sanitation, and hygiene
WHO	World Health Organization

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Annexes

Annex 1. Organisations and networks currently involved in the Epidemic Intelligence from Open Sources (EIOS) initiative

At present, the EIOS initiative involves the following international organisations and previously existing initiatives:

- World Health Organisation (WHO), as leader of the initiative
- Global Health Initiative (GHSI). The members of this partnership are Canada, the European Commission, France, Germany, Italy, Japan, Mexico, the United Kingdom, and the United States. In the scope of this collaboration, following institutions actively participate in public health surveillance activities through the EIOS system:
- Public Health Agency of Canada.
- European Centre for Disease Control (ECDC).
- Robert Koch Institute, Germany
- Instituto Superiore di Sanità (Italian National Institute of Health), Italy.
- Ministry of Health, Labour and Welfare, Japan
- National Institute of Infectious Diseases, Japan
- Ministry of Health, Mexico
- Public Health England
- Centers for Disease Control and Prevention (CDC), United States
- Food and Agriculture Organization of the United Nations (FAO)
- World Organization for Animal Health (OIE)
- Joint FAO–OIE–WHO Global Early Warning System (GLEWS).
- Africa Centres for Disease Control and Prevention (Africa CDC)
- Global Outbreak Alert and Response Network (GOARN).
- United Nations International Children's Fund (UNICEF).
- United Nations Office on Drugs and Crime (UNODC)
- Médecins Sans Frontières (MSF)

Moreover, national health authorities the following WHO member states are actively participating to the EIOS initiative, while other countries are expected to join in the future:

- Albania
- Argentina
- Brazil
- Egypt
- Republic of Korea
- Republic of Moldova
- Nepal
- Nigeria
- Oman
- Republic of Singapore
- Uganda

Annex 2. INFORM Steering group and partners

The INFORM steering group includes the following organisations:

- ACAPS
- European Commission, Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO)
- European Commission, Joint Research Centre
- Food and Agriculture Organization of the United Nations (FAO)
- International Organization for Migration (IOM)
- United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
- Organisation for Economic Co-operation and Development (OECD)
- Foreign, Commonwealth & Development Office, United Kingdom (FCDO)
- United Nations Development Programme (UNDP)
- United Nations High Commissioner for Refugees (UNHCR)
- United Nations International Children's Fund (UNICEF).
- World Food Programme (WFP)
- World Health Organisation (WHO)

The following partners are also involved:

- Batten Global - Global Policy Center, UVA's Frank Batten School of Leadership and Public Policy
- Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)
- Global Facility for Disaster Reduction and Recovery (GFDRR)
- Insurance Development Forum (IDF)
- Internal Displacement Monitoring Centre (IDMC)
- International Federation of Red Cross and Red Crescent Societies (IFRC)
- Ludwig Maximilian University of Munich (LMU)
- Pacific Disaster Center (PDC)
- START Network
- United Nations Department of Political and Peacebuilding Affairs (UNDPA)
- United Nations Office for Disaster Risk Reduction (UNDRR)
- United Nations Environment Programme (UNEP)
- United Nations Population Fund (UNFPA)
- Institute for Environment and Human Security, United Nations University (UNU-EHS)
- UN WOMEN
- United States Department of State

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