

Attributes less commonly used in the evaluation of surveillance systems

Less commonly used attributes belong to different classes such as Organization (*systemic organization, suitability of the system objectives, field institutional organization and laboratory*), Implementation (*coordination, data analysis, data collection, data management, evaluation and performance indicators, surveillance procedures, surveillance tools, stability, reliability and training*), Performance (*probability of type I and type II error, specificity, positive predictive value (PPV), negative predictive value (NPV), efficiency, coverage, false positive, false negative, early detection capacity, communication, information distribution*), Impact (*benefit, net value (of the programme), margin over intervention*), and One health approach (*OH working, OH thinking, OH sharing, OH planning, OH learning*).

Systemic organization (also referred to as *surveillance system organization* or *central institutional organization*) was used in 7.6% (12/157) of evaluations to assess the organizational structures, management and/or leadership of the system. Specifically, this attribute is reported in four studies conducted in Europe: two evaluating the One health (OH) aspects of surveillance for Taeniasis and Cysticercosis (Fonseca et al., 2018) and Tick-borne diseases (Garcia-Vozmediano et al., 2022), one assessing the system's ability to detect cases of Salmonella in cattle (Peyre et al., 2015) and one comparing the performance of three surveillance systems for equine diseases (Amat et al., 2015).

Suitability of the system objectives (or *objectives and scope of surveillance*), used in 2.5% (4/157) of the evaluations, assesses the relevance and completeness of a surveillance systems' objectives, the extent to which partners' expectations are considered, and the alignment of the diseases under surveillance with the health situation (Hendrikx et al., 2011; Rivers et al., 2023).

The organizational attributes *field institutional organization* and *laboratory* were each used in three evaluations (1.9%, 3/157) to assess, respectively, the existence, roles and activities of intermediate units over the territory, the exhaustiveness or representativeness of coverage of the target population by agents in the field, and the integration of the laboratory into the surveillance system, including– but not limited to – the standardization and quality of work, diagnostic techniques and returned results (Amat et al., 2015; Hendrikx et al., 2011). The same evaluations used also the attributes *surveillance procedures*, assessing the existence of surveillance operations that are relevant to the system's objectives and their ability to generate relevant and comprehensive results, *surveillance tools*, which evaluates the surveillance protocols, and *evaluation and performance indicators*, referring to the development, validation and calculation of performance indicators, the implementation of external evaluations and the corrective measures subsequently adapted (Amat et al., 2015; Hendrikx et al., 2015).

Data collection assesses the use of appropriate data sources and collection methods, as well as the existence of a case definition and a data collection protocol, while *data management* evaluates the structure and documentation of data management systems (Drewe et al., 2017). Both attributes were used in 2.5% (4/157) of evaluations (Amat et al., 2015; Drewe et al., 2017). *Data analysis*, which examines the completion of comprehensive descriptive data analysis and the suitability of data for epidemiological analysis (Hendrikx et al., 2011), was applied in 1.9% (3/157) of the evaluations (Amat et al., 2015).

Stability is defined as the reliability (i.e. the ability to collect, manage, and provide data properly without failure) and availability (the ability to be operational when it is needed) of the surveillance system (German et al., 2001), and it was employed in 13.4% (21/157) of surveillance systems evaluations, with a greater prevalence in studies focused on human health (14/54, 26%) (Alemu et al., 2019; Ario et al., 2022; Awekeya et al., 2021; Babaie et al., 2015; Hunduma and Leulseged, 2021; Maponga et al., 2014; Mremi et al., 2023; Ng'etich et al., 2021; Prajapati et al., 2023; Qurat ul Ain et al., 2019; Rumunu et al., 2022; Schwind et al., 2014; Umeozuru et al., 2022; Van Boetzelae et al., 2020) and in studies evaluating systems in Africa (as it is found in 12/30, 40% of evaluations conducted in this Region). *Reliability* was assessed independently in one study (Amat et al., 2015) evaluating surveillance for equine diseases.

Training, reported in 2.5% (4/157) of evaluations, encompasses the financial resources allocated, the nature and duration of training provided to surveillance personnel, and the proportion of actors who have received training (Amat et al., 2015; Hendriks et al., 2011; Rumunu et al., 2022). This includes both frontline staff, such as officers and health facility workers (Rumunu et al., 2022), and professionals involved in data analysis, interpretation, and dissemination (Muellner et al., 2018).

Coordination (1.9%, 3/157 of the evaluation) assesses the coordination and supervision of the surveillance network (Amat et al., 2015; Hendriks et al., 2011). Similarly, *supervision and feedback*, found only in one evaluation, refers to the extent and frequency of supervision by higher-level authorities, and the provision of feedback to the reporting sites (Rumunu et al., 2022).

The *probability of Type I error*, also referred to as *False alarm rate* is defined as the probability of a non-infectious unit or population being classified as infected (Grosbois et al., 2015; Jamin and Rivière, 2020), leading to the activation of unnecessary mitigation measures. It was used in 3.2% (5/157) of the evaluations, of which two were conducted in Europe, assessing the effectiveness of multivariate syndromic surveillance using animal health data (Vial et al., 2016) and bovine tuberculosis surveillance (Jamin and Rivière, 2020), while the other evaluations consisted in two contrived examples and one empirical case study on avian influenza surveillance taking place in Asia, all of which were presented in one study (Grosbois et al., 2015). The last two of the three aforementioned studies evaluated also the probability of a *Type II error*, namely the probability of an infectious unit or population being classified as non-infected, resulting in the failure to activate the necessary mitigation measures and an increased risk of failure to control a disease threat (Grosbois et al., 2015; Jamin and Rivière, 2020).

Specificity, defined as the proportion of true non-events correctly classified as such (Drewe et al., 2017), was present in 5.1% (8/157) of surveillance systems evaluations, all of which were conducted in Europe and targeted bovine tuberculosis (Drewe et al., 2017), salmonellosis (Foddai et al., 2021), syndromic disease surveillance in cattle (Faverjon et al., 2019), contagious equine metritis, equine infectious anemia, equine viral arteritis (Amat et al., 2015), and West Nile disease in horses (Faverjon et al., 2017, 2016).

Positive predictive value (PPV) is defined as the proportion of reported cases that actually have the health-condition under surveillance, and it was employed to evaluate 13.4% (21/157) of the surveillance systems, with a greater usage in human health evaluations (16/54, 30%) (Alemu et al., 2019; Ario et al., 2022; Awekeya et al., 2021; Debnath and Ponnaiah, 2018; Hunduma and Leulseged, 2021; Porcu et al., 2023; Qurat ul Ain et al., 2019; Ratnayake et al., 2016; Thomas et al., 2018; Umeozuru et al., 2022; Van Boetzelaer et al., 2020) than in surveillance systems targeting animal health (5/103, 4.9% of evaluations targeting animals, alone or along with humans) (Faverjon et al., 2019; Foddai et al., 2021; Jamin and Rivière, 2020; Lopes et al., 2016; Waziri et al., 2014).

Negative predictive value (NPV), defined as the probability that a negative test result accurately indicates the absence of the condition in an individual or group (Jamin and Rivière, 2020), had a limited application (3/157, 1.9% of the evaluations) and was applied only in animal health surveillance evaluations (Faverjon et al., 2019; Foddai et al., 2021; Jamin and Rivière, 2020) – the same as *efficiency*, which refers to the effectiveness of the surveillance system in reducing the occurrence of the disease by optimizing the financial, human, and material sources deployed (Collineau et al., 2013; Gervasi et al., 2020; Mercier et al., 2020).

Coverage was used to assess the proportion of the target population included in the surveillance system in 8.3% (13/157) of the evaluations (Drewe et al., 2017; Ely et al., 2012; Mala et al., 2021; Mercier et al., 2020; Peyre et al., 2015; Vredenberg et al., 2022).

False positive and *false negative* are defined, respectively, as the likelihood of the system to incorrectly identify a positive case and failing to detect true events. These definitions complement those of *specificity* and *sensitivity*, providing an alternative perspective to evaluate the same characteristics. These attributes

have both been applied to a limited extent (2/157, 1.3% of the evaluations), restricted to evaluations using simulation models (Foddai et al., 2021; Porcu et al., 2023) and one application of prospect theory (Attema et al., 2019).

Early detection capacity (used in 2/157, 1.3% of the evaluations) assessed the ability to detect the circulation of a disease prior to its transmission to a different host population, specifically for West Nile disease (Bellini et al., 2014; Chaintoutis et al., 2014).

Communication (3.2%, 5/157) and *information distribution* (or *external communication and dissemination*) (1.9%, 3/157) encompass the exchange of information and feedback among all levels of the surveillance system. This includes the methods and timeliness of information flow, systematic dissemination of surveillance reports, and engagement with stakeholders such as data providers (e.g., farmers, veterinary authorities), surveillance analysts, users and other relevant beneficiaries (Amat et al., 2015; Drewe et al., 2017; Hendrikx et al., 2011; Hunduma and Leulseged, 2021). These attributes served to assess both systems targeting animal health (Amat et al., 2015; Drewe et al., 2017) and human health (Hunduma and Leulseged, 2021).

Benefit (used in 7/157, 4.5% of the evaluations) evaluates the direct and indirect positive outcomes, both monetary and non-monetary, generated by surveillance activities (Calba et al., 2015a; Drewe et al., 2017; Peyre et al., 2019). These benefits may include animal health and welfare, disease costs reduction, financial savings, optimized resource use, improved animal production, enhanced access to international market for live animals and animal products, increased trade, better public health outcomes (especially for zoonoses), and greater consumer confidence (Calba et al., 2015b; Drewe et al., 2017; Peyre et al., 2019). It was applied in surveillance systems targeting animal health (Calba et al., 2015a; Delabougliose et al., 2016; Drewe et al., 2017; Guo et al., 2014; Häslér et al., 2012c, 2012a) and one system assessing zoonoses surveillance in a One Health context (Babo Martins et al., 2016). The evaluations were conducted predominantly in Europe, with one conducted in Asia.

Margin over intervention and *net value of the programme* were used in two studies applying an economic model for the evaluation of surveillance programmes for bluetongue (Häslér et al., 2012a) and bovine viral diarrhoea (Häslér et al., 2012c) in Europe. They correspond, respectively, to the maximum expenditures potentially available for surveillance without the net benefits from mitigation overall becoming zero, and the overall net value of surveillance.

All of the attributes included in the class One health approach (*OH learning, OH planning, OH sharing, OH thinking and OH working*) were used in two studies (4/157, 2.5% of the evaluations) which applied the framework Network for the Evaluation of One Health (NEOH), evaluating surveillance systems for tick-borne diseases (Garcia-Vozmediano et al., 2022) and the design of taeniasis and cysticercosis surveillance (Fonseca et al., 2018) in Europe. These attributes examine the knowledge exchange infrastructure, planning and resource allocation, methods of information, data sharing, the dimensions involved or affected by the health issue, their alignment with the One health initiative, as well as interdisciplinary and participatory engagement.

Some of the attributes were utilized in only one evaluation. This is the case for attributes that were employed in a specific framework, such as *minimum sample size, stakeholder analysis* and *true prevalence*, which were used in a framework proposed by Rivers et al. (2023). Ohashi et al. (2010) evaluated the qualitative aspects of bovine spongiform encephalopathy through the analytic hierarchy process (AHP), using factors (which, for the purpose of this manuscript, were assumed as attributes) like *surveillance planning, execution of surveillance, group subject to inspection, compliance with related systems* and *appropriateness of test method*. Drewe et al. (2017) applied the framework SERVAl (SuRveillance EVAluation framework) to a case study aimed at evaluating pre-movement testing for bovine tuberculosis in Europe, introducing the attributes *participation*, which is the equivalent of *acceptability*, and *impact*, which measures the usefulness

of the system. Peyre et al. (2015) developed several case studies in order to develop and validate the framework RISKSUR EVA tool (Peyre et al., 2019), using *precision*, which defines how closely a numerical estimate is, *detection fraction*, which in the final list of attributes provided by the framework is included as a part of the attribute *sensitivity*, and *availability and sustainability*, referring to the ability to be operational when needed (availability) and the robustness and ability of the system to be ongoing in the long term (sustainability), a definition which closely resembles the one of *stability* provided by CDC (German et al., 2001). *Robustness* by itself was utilized in the work of Porcu et al. (2023) which evaluated a web-based syndromic system for Covid-19 in Europe. Furthermore, *procedure*, applied in the study of Hunduma and Leulseged (2021) refers to the ability to carry out the operations required by the surveillance system. Two attributes, namely *effectiveness* and *effectiveness of outbreak detection*, were both utilized in the evaluation of avian influenza surveillance in Europe. *Effectiveness*, meaning the extent to which a given technical objective, or target, is achieved, was assessed to perform a cost-effectiveness analysis (Häsler et al., 2012b). *Effectiveness of outbreak detection* was measured to assess surveillance strategies for the early detection of low pathogenic avian influenza infections (Comin et al., 2012), using the farm reproduction number (R_0), which corresponds to the estimated average number of outbreaks caused by a single infected epidemiological unit, evaluating if the detection occurs soon enough to bring an epidemic under control. *Area specificity* was employed to assess the capacity of the surveillance to indicate the spatial risk of a disease in the host population for West Nile disease (Bellini et al., 2014). A subset of the attributes employed exclusively in a single evaluation served to assess surveillance systems using short message services. *Technological evaluation* was used to assess the availability of technology required to perform surveillance activities of a public health surveillance system in Africa (Randriamiarana et al., 2018), which was reinforced through the adoption of short message services, in contrast to paper-based forms. Stewart et al. (2019) evaluated the *feasibility*, meaning the time spent following up the alerts generated by a text-based system targeting influenza A (H3N2)v in humans. *Usability* assessed the ease of use of a SMS-based smartphone application in Africa (El-Khatib et al., 2018), and *response rate* was used to assess the average daily response rate for SMS in a surveillance system in Oceania targeting avian influenza in humans (Stephenson et al., 2016).

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