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INVITED PAPER

Bridging digital transformation in public health with digital responsibility

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Abstract

The rapid digitalization of public health systems demands a framework to ensure the responsible implementation of digital technologies. The Digital Responsibility (DR) framework, proposed by Trier et al. (2023), can serve this purpose but requires further contextualization — an objective pursued in this paper. We apply a content analysis approach to map the DR principles and levels to the Public Health Agency Maturity Model (PHAMM), which is widely used in the German public health service (PHS) to assess digital maturity and derive actions for its advancements. By mapping 354 PHAMM criteria to the DR framework, we identified areas for improvement in both models, contextualized DR for the PHS by identifying 16 subthemes, and extended the DR framework. The extended framework was discussed and evaluated in a focus group with nine experts. This process led to complementing the existing DR levels with an inter- and intracorporate relation and introduces an additional DR principle (Security). Moreover, the study draws crosscutting lessons learned.

Keywords Digital Responsibility · Public health · Digitalization · Maturity model · Public health agencies

JEL Classification I18 · M15 · O33

Introduction

As digital technologies become increasingly embedded in societal infrastructure and everyday practices, their ethical, societal, and regulatory implications are gaining urgency (Hess et al., 2014; Chatterjee & Sarker, 2024; van de Poel et al., 2022). These technologies enable new forms of efficiency, personalization, and service innovation (Jansen et al., 2024; Kane et al., 2023; Wessel et al., 2021). Yet, they also introduce risks, including privacy erosion, discrimination, misinformation, and other dysfunctional digital outcomes that have been documented in recent Information System (IS) research (Benbya et al., 2020; Berente et al., 2021; Recker et al., 2025). This duality illustrates that digital transformation simultaneously generates substantial benefits and systemic risks (Bartelheimer et al., 2024; Elliott et al., 2021).

In response to the risks associated with digitalization and the growing demands for sustainability, the concept of Digital Responsibility (DR) has emerged as a governance approach to manage the dual nature of digital transformation (Trier et al., 2023). DR offers a value-based foundation for digital transformation that extends beyond regulatory

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compliance (De Lange et al., 2012; Trier et al., 2023) and provides normative guidance for balancing digital opportunities with the ethical and societal risks they generate. So far, DR has been predominantly used and studied in corporate settings, frequently under the concept of Corporate Digital Responsibility (CDR; e.g., Lobschat et al., 2021; Mueller, 2022). Yet, this narrow focus limits the understanding of how DR unfolds in more complex, multi-stakeholder contexts (Recker et al., 2025) and is therefore insufficient for addressing the broader societal consequences of digital transformation. Against this backdrop, Trier et al. (2023) emphasize the need to broaden the discourse, calling for consideration of a more comprehensive perspective on DR and a wider range of stakeholders.

Public-sector contexts, in particular, involve diverse and interdependent stakeholders and carry heightened obligations for fairness, transparency, and accountability, which require a more expansive conceptualization of DR that goes beyond corporate governance logics. The degree to which public institutions adopt DR shapes how digital services are designed and governed. This, in turn, influences citizens' rights, equitable access to services, and ultimately trust in democratic institutions (Chauvin & Lomazzi, 2017; Kokkoris & Kamleitner, 2020; Malvey & Slovensky, 2017).

An example of DR's relevance in the public sector is Germany's public health service (PHS). Here, Public Health Agencies (PHA) play a central role in implementing health protection, disease prevention, and health promotion (Rechel et al., 2018). Due to longstanding underfunding, fragmented IT infrastructures, and overlapping responsibilities across municipal, state, and federal levels, German PHA face digitalization challenges. The COVID-19 pandemic exposed these vulnerabilities, revealing deficits in digital preparedness, including interoperability and insufficient digital capacity (Gunasekeran et al., 2021). These challenges are amplified by the sector's handling of sensitive health data and its mandate to ensure equitable access to care (Doctor et al., 2023).

In response, the German government, like many other governments, launched large-scale investments to accelerate PHA digitalization (Federal Ministry of Health, 2024; NHS, 2019). These initiatives led to the rapid deployment of digital tools, such as contact tracing apps and digital reporting systems for infection handling, which facilitated the digitalization of PHA in general. However, this transformation also raised concerns about privacy, autonomy, and digital exclusion (Gunasekeran et al., 2021; Kokkoris & Kamleitner, 2020). As digitalization progressed, further risks emerged, including algorithmic bias, data misuse, and erosion of public trust (Flores et al., 2023; Velmovitsky et al., 2021). Addressing these challenges and guiding responsible digital transformation in the future calls for a structured and ethically grounded approach like DR, which is especially suited in sensitive and highly regulated domains like public health, as it combines normative orientation (e.g., fairness, inclusiveness) with practical governance structures (e.g., principles and levels) that can be tailored to sector-specific needs.

This study applies the DR framework proposed by Trier et al. (2023), which offers a straightforward structure comprising eight principles and three levels, to the digital transformation of PHA in Germany. To apply this framework to the public health sector, we utilize the Public Health Agency Maturity Model (PHAMM). The PHAMM is the leading instrument for guiding and assessing digital maturity across the 380 German PHA (Doctor et al. 2023). Developed in response to the COVID-19 pandemic, the PHAMM captures eight key digitalization dimensions — from IT security and process digitalization to citizen focus and interoperability — and operationalizes them across five maturity levels. Given its structured approach, the PHAMM offers the opportunity to investigate how DR is reflected in public health digitalization and where blind spots remain. This leads to our first research question (RQ1):

RQ1: To what extent does the PHAMM-guided PHA digitalization reflect the DR principles and levels?

Building on this analysis, we explore how applying the DR framework in PHS can generate theoretical insights into the DR framework itself and its application within a public, non-corporate context. These insights may point to blind spots, highlight contextual requirements, or suggest conceptual extensions of the existing framework by Trier et al. (2023). This leads to our second RQ:

RQ2: What refinements to the DR framework emerge from its application in the PHS?

To answer the two RQ, this study employs a deductive content analysis approach following Mayring (2015) by mapping the 354 PHAMM criteria to the DR framework. The content analysis results are then evaluated in a focus group of DR practitioners, PHA experts, and maturity model experts. This paper makes several contributions. First, it applies DR principles and levels to the PHAMM, identifying areas for extending the model and thereby better capturing DR's complex and multilevel nature (Recker et al., 2025), which facilitates responsible digitalization in German PHA. Second, it validates and contextualizes the DR framework for the PHS, addressing calls to adapt the principles to specific application contexts (Carl & Hinz, 2024) and going beyond the currently prevailing corporate focus of the discourse (Trier et al., 2023). Third, it refines the DR framework by introducing a new principle (**Security**) and complements the existing structural DR levels with two new relational configurations (**Intra-** and **Intercorporate**), which increase the framework's applicability and operational value. These advancements make the DR framework more

adaptable and actionable for researchers and practitioners in the field of digital health transformation.

The remainder of this paper is structured as follows. The "Theoretical Background" section introduces the theoretical background on DR, its principles and levels, and the background on public health. The "Method" section describes the research method, including PHAMM as the empirical foundation of the study, as well as the approach of content analysis and focus groups. The "Results" section presents the results of the content analysis and contextualization. The "Discussion" section discusses the refinements to the DR framework, integrating both empirical findings and expert insights, derives lessons learned, explains limitations, and implications for research and practice. The "Conclusion" section concludes the study.

Theoretical background

Digital responsibility

The continuous, ongoing and ubiquitous digital transformation reshapes personal life, society, and organizations (Recker et al., 2025). In the corporate context, digital technologies can help in reducing manual work (Dengler & Matthes, 2018) and facilitating digital business models (Veit et al., 2014). At the individual level, digital applications such as meditation apps can promote well-being (Bostock et al., 2019) and communication software such as messengers, emails and social networks can ease social interactions and exchange (e.g., Chan & Leung, 2018; Chukwuere, 2021). Even at the societal level, concepts such as e-government can facilitate bureaucratic processes and improve citizens' access to governmental services and participation (Dike, 2019; Tejedo-Romero et al., 2022). While these advancements benefit consumers, citizens, and employees, they also introduce risks and challenge traditional markets (Trier et al., 2023). For example, health applications raise concerns about the privacy of sensitive data collected through these systems (Papageorgiou et al., 2018), social media platforms have been shown negatively affect mental health (Braghieri et al., 2022) and the use of information and communication technology in organizations can lead to digital stress and thus, reduced performance (Tarafdar et al., 2015). In response to this "dark side" of digital transformation, regulatory landscapes are evolving (Dörr, 2021; Markus & Rowe, 2023), affecting compliance practices and organizational strategies to address and mitigate those negative effects of digital technologies (Markus & Rowe, 2023). At the same time, societal expectations urge institutions to address environmental responsibilities (De Lange et al., 2012). This dual pressure of digitalization and sustainability, along with the need to mitigate the risks of digital technologies, has given rise to DR as a foundation for responsible digitalization (Trier et al., 2023), a concept that has been of growing interest in IS research (Recker et al., 2025; Trittin-Ulbrich et al., 2025).

Trier et al. (2023) define DR as "the efforts of stakeholders such as individuals, corporations, or public institutions to contribute to a sustainable, more inclusive, fair, and value-based digital society (or digitalization in general) beyond the legal minimum" (p. 463). DR is operationalized through organizational measures in companies to ensure CDR (Trier et al., 2023) and needs to be distinguished from Corporate Social Responsibility (CSR), a management approach to integrate social and environmental considerations into organizational strategies and operations (Mihale-Wilson et al., 2022). CSR prioritizes corporate accountability, promoting ethical conduct, sustainability, and active community engagement (Cominetti & Seele, 2016). Although widely studied, CSR lacks a standardized definition and agreed-upon core principles (Mihale-Wilson et al., 2022). Instead, it offers a range of voluntary regulatory implementation paths for organizations. This absence of clearly defined CSR mechanisms challenges governments to enforce CSR (van der Merwe & Al Achkar, 2022).

Distinct from the business-oriented focus of CSR, DR addresses the ethical, value-based, and societal challenges digital technologies pose (Mueller, 2022; Trier et al., 2023; van der Merwe & Al Achkar, 2022). In recent years, the importance of DR has grown within corporate contexts (van der Merwe & Al Achkar, 2022), where it is increasingly operationalized through CDR initiatives (Trier et al., 2023). Herden et al. (2021) define CDR as "an extension of a firm's responsibilities which takes into account the ethical opportunities and challenges of digitalization" (p. 17). While CDR and CSR share overlapping themes (Carl et al., 2022), they are not interchangeable. Some scholars consider CDR as a natural extension of CSR with similar implementation mechanisms (van der Merwe & Al Achkar, 2022; Carl et al., 2022; Weber-Lewerenz & Traverso, 2025), while others argue for a clear conceptual distinction (Lobschat et al., 2021). For instance, Lobschat et al. (2021) highlight CDR's unique stakeholder interactions in digital contexts — addressing employees and shareholders but also indirect and long-term effects on society. Reflecting these differences, van der Merwe and Al Achkar (2022) caution against reproducing the shortcomings of CSR, which often failed to generate tangible impact due to its voluntary character, and argue for stronger regulatory embedding of CDR. In this light, Trier et al. (2023) describe DR as a potential "second wave" (p. 463) of responsibility that accounts for unintended consequences and broader stakeholder constellations. This forward-looking orientation has drawn the interest of political actors and business associations, who increasingly view DR as a relevant governance concept.

Still, (C)DR has been primarily studied for corporate organizations operating in a business context (Mueller, 2022; Trier et al., 2023). Due to its company focus, CDR research has yet to explore broader levels of responsibility (e.g., societal, legal) and the interaction between those levels and diverse stakeholders. Likewise, a comprehensive ecosystem perspective on DR — such as an industry-wide approach — remains underdeveloped (Trier et al., 2023). Public sectors, such as the PHS, can offer such a non-company perspective on DR. Mueller (2022) provided a first public sector contextualization and emphasized democratic accountability, transparency, and citizen trust as key responsibilities for public institutions navigating digitalization. While this translation offers an important conceptual foundation, it remains largely theoretical and lacks an operational structure for analyzing and shaping responsible digitalization processes within public institutions. Developing an operational structure, or a more specific contextualization of DR to concrete application scenarios, is essential for effective implementation (Carl & Hinz, 2024).

Trier et al. (2023) proposed a DR framework to guide the understanding and implementation of responsible digitalization. The DR framework includes eight DR principles, three levels, and eight exemplary research themes (see Fig. 1).

DR principles are "fundamental and value-based normative requirement[s]" (Trier et al., 2023, p. 464), aiming at guiding behavior and evaluations of digital technologies and their development and implementation (Trier et al., 2023). Table 1 gives an overview of the DR principles and exemplary references. Each of the eight DR principles focuses on a different DR aspect, and together, they form a foundation for promoting holistic, responsible digitalization (Trier et al., 2023). The principles outlined in the DR framework operate across three interconnected levels: Societal, Corporate, and Personal. The Societal level emphasizes the role of the state and supranational institutions in fostering sustainable digitalization through effective policy-making and regulatory frameworks. The Corporate level focuses on the ethical values and operational standards that guide companies in promoting sustainable, transparent, and inclusive behaviors when deploying digital technologies. The Personal level emphasizes individual responsibility in engaging ethically within digital activities. As Carl and Hinz (2024) highlighted, the DR framework requires context-specific adaptations, particularly in highly regulated sectors such as public health. While Table 1 provides initial and exemplary insights into DR principles within public health, a comprehensive understanding of all principles and levels of the DR framework in public health is missing.

Public health, digitalization, and digital responsibility

Public health systems promote health, prevent disease, and protect populations through coordinated policies, services, and interventions, including health promotion, infection tracking, and medical services (Wolf et al., 2024). Some nations operate centralized public health systems with decision-making concentrated at the national level, while others rely on a decentralized approach (Kuhlmann et al., 2021; Rechel et al., 2018). Germany, for example, follows a decentralized approach with responsibilities being divided among federal, state, and municipal levels (Doctor et al., 2023). At the municipal level, approximately 380 PHA are responsible for disease prevention, health promotion, and monitoring of environmental factors (Adaeze Nwobu, 2022). While national institutions like the Federal Ministry of Health and the Robert Koch Institute provide strategic oversight, PHA

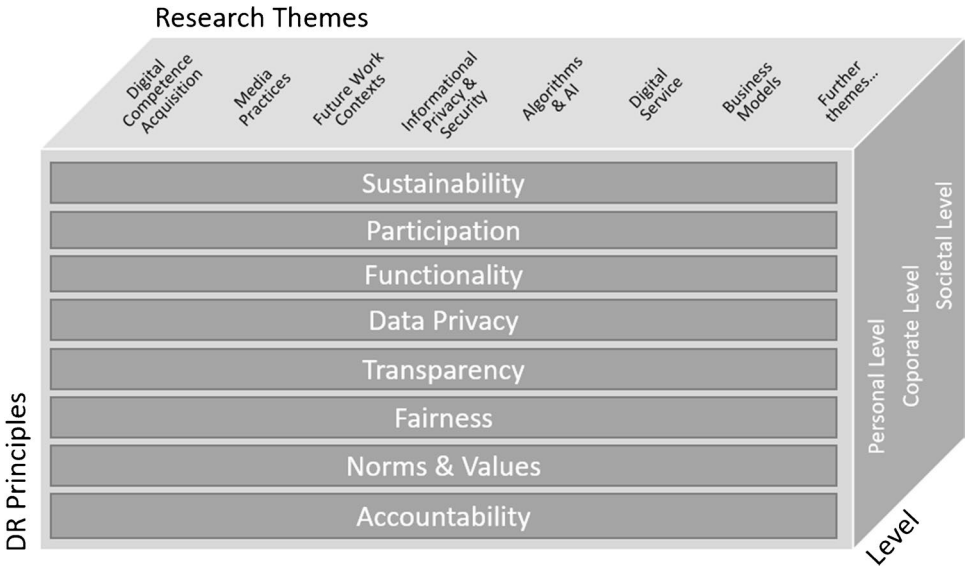

Fig. 1 DR framework based on Trier et al. (2023)

Table 1 DR principles with definition and general and public health specific literature based on Trier et al. (2023)

Definition of DR principles	General literature	Public health literature
Sustainability requires balancing digital benefits with environmental protection by integrating social and ecological aspects into digital strategies, while political incentives support this through broader societal efforts	Bican and Brem (2020), Orbik and Zozuľaková (2019)	Saisó et al. (2022)
Participation promotes inclusive digital processes. Social initiatives address the digital divide through training and skills development	Jobin et al. (2019), Mihale-Wilson et al. (2021)	Wolf et al. (2024), Hinsche-Böckenholt et al. (2023)
Functionality ensures technologies serve societal needs by complying with legal and ethical standards like the General Data Protection Regulation	Koçak et al. (2013)	Allem and Ferrara (2018), Barbarito et al. (2012), Wolf et al. (2024)
Data Privacy ensures individual control over digital identities, supported by corporate data governance and legal safeguards	Jobin et al. (2019), Mihale-Wilson et al. (2021), Thorun et al. (2017)	Kokkoris and Kamleitner (2020), Velmovitsky et al. (2021), Wacksman (2021)
Transparency empowers users by clarifying data value and enabling understandable AI-driven services, while promoting accountability in political decision-making	Jobin et al. (2019), Mihale-Wilson et al. (2021), Thorun et al. (2017)	Gutierrez et al. (2023), Velmovitsky et al. (2021)
Fairness promotes equal digital access, respects intellectual property, and calls for transparent, unbiased AI to ensure equitable outcomes	Alsaleh (2024), Jobin et al. (2019), Orbik and Zozuľaková (2019)	Juvalta et al. (2023), Raza et al. (2024), Kaufmann et al. (2023)
Norms & Values call for embedding ethics like trust, autonomy, and well-being into digital development, fostering global standards and a shared digital society	Lobschat et al. (2021), Orbik and Zozuľaková (2019)	Lewerenz et al. (2025)
Accountability clarifies responsibility for DR through organizational governance, legal liability, and global efforts to support digital equity	Heeks (2022), Mihale-Wilson et al. (2021), Orbik and Zozuľaková (2019), Thorun et al. (2017)	AlKnawy et al. (2023), Cooney et al. (2018)

implement public health strategies locally. PHA in Germany — like in other countries — received little public attention for many years (Arnold & Teichert, 2021). The COVID-19 Pandemic changed the situation, exposing staff shortages and inadequate digital infrastructure in PHA, highlighting the consequences of long-standing underfunding. In response, numerous countries have invested in digitalizing their public health systems (Doctor et al., 2023).

While the subsequent digitalization of the PHS is widely regarded as a necessary advancement, it has also sparked debates about the risks of digitalization. On the one hand, scalable digital solutions, such as contact tracing apps, enabled the rapid containment of disease spread. On the other hand, they raised concerns about the tradeoff between privacy concerns and the freedom facilitated by these apps (Kokkoris & Kamleitner, 2020). This tension exemplifies a challenge in responsible digitalization in public health. Dockweiler and Razum (2015) explain that it involves balancing individual autonomy with external control in the context of automated health data collection. This example illustrates why public health is an essential sector for DR.

Furthermore, unequal access to digital resources and the inconsistent use of digital services (Kaufmann et al., 2023) reinforce the need for DR approaches in public health. For instance, while some PHA offer online information sessions, others do not, creating disparities in access. Another challenge is the imbalance of digital health literacy across society, reflecting unequal competencies in handling digital technologies (Juvalta et al., 2023). The unequal access to digital resources and the varied ability to utilize them underscore shortcomings in the DR principles of Participation and Fairness. With new technologies such as artificial intelligence (AI) in public health, issues such as fairness are becoming even more critical (Raza et al., 2024). In this regard, the challenge lies in ensuring the Transparency and Accountability of AI systems while integrating ethical considerations pertinent to their applications in public health. In summary, the growing need for responsible digitalization is underscored by the rapid influx of innovations, which often lead to unintended consequences and unforeseen side effects (Chauvin & Lomazzi, 2017; Malvey & Slovensky, 2017). Insufficient discussions on associated risks highlight the need for a tailored public health DR framework to guide responsible digitalization in public health systems.

Method

Data background to the framework of public health digitalization in Germany

In Germany, the PHS is actively working towards its digital transformation. In doing so, PHA use the PHAMM to evaluate and enhance their digital maturity (Doctor et al., 2023), which serves as our study's empirical foundation. The PHAMM consists of eight dimensions (see Table 2) with multiple subdimensions and includes 354 criteria that define digitalization measures across five maturity levels (Doctor et al., 2023). PHA rate the implementation status of each criterion to assess their digital maturity. Once the maturity

Table 2 (Sub-)Dimensions of the PHAMM (Reprinted from Doctor et al., Wolf et al., 2024)

Dimension	Description, including subdimension
Digitization strategy	The dimension *digitalization strategy* comprises (1) **the definition, communication, and implementation** of the digitalization strategy, the (2) **definition of responsibilities**, and the planning of the necessary (3) **digitalization budget** for the PHAs' tasks and objectives
Employees	The dimension *employees* includes the (1) **sensitization** and (2) **participation** of the employees in digitalization activities, as well as the aspects of (3) **training** possibilities
Process digitalization	The dimension *process digitalization* includes: the extent to which processes are (1) **documented**, the extent to which processes are (2) **IT-supported**, and the extent to which there are (3) **overlapping processes** to be addressed via cross-process coordination. Finally, we lay out criteria for the (4) **evaluation of processes** across tasks and departments
IT security	The dimension *IT security* includes the scope of (1) **IT security management**. It also addresses concrete measures for (2) **dealing with IT security risks and attacks** as well as (3) **identity and access management**
IT provision	The dimension *IT provision* includes the equipment of the (1) **IT workplace** (hardware and operating systems), the (2) **organization of the IT procurement** and of the (3) **IT infrastructure**, and the (4) **application of IT service processes**
Citizen focus	The dimension *citizen focus* includes the consideration of the (1) **interaction** with citizens and orientation and design of the available information (2) **preferences**
Cooperation	The dimension *cooperation* includes (1) **cooperation within the public health departments**, (2) **cooperation between health departments among themselves and with provincial offices**, and (3) **cooperation with external stakeholders**
Software, data, and interoperability	The dimension *software, data, and interoperability* includes the (1) **use of specialist applications** as well as their (2) **technical interoperability**, (3) **data analysis and reporting**, (4) **requirements and documentation** of specialist applications, and (5) the **protection of data**

assessment is completed, the PHA use the results to apply for national funding provided by the Pact for the PHS (Federal Ministry of Health, 2024).

Supported by the PHAMM (Doctor et al., 2023) and funding from the Pact for the PHS (Federal Ministry of Health, 2024), PHA have had the opportunity to advance their digital maturity since 2022. However, decades of underfunding and the complexities of federal governance have posed challenges (Doctor et al., 2023). The initial PHAMM assessment (evaluation date: 31.12.2021) highlights these disparities in the PHA digital readiness (see Fig. 2). Many PHA rated their digital maturity at level 0 or did not reach any level. The lowest maturity levels were observed in process digitalization, software, data, and interoperability, as well as IT security. In contrast, the latest published PHA self-assessment (evaluation date: 31.12.2023) shows notable progress (Eymann et al., 2024). Overall, maturity levels have risen, with fewer PHA remaining at level 0 and more agencies advancing towards higher maturity stages.

While the self-assessment results (see Fig. 2) indicate progress, most agencies remain in the early stages of their digital journey. The distinction between digitization, digitalization, and digital transformation is helpful to contextualize this progress (Merbecks, 2024). Digitization refers to converting analog processes into digital formats without fundamentally altering workflows. Digitalization builds upon this by integrating digital technologies into organizational processes, enhancing efficiency and interoperability. Digital transformation represents a more profound shift characterized by fully integrated digital systems, strategic realignment, and cross-organizational collaboration (Merbecks, 2024). As agencies move from digitization towards more integrated transformation, the relevance of CDR initiatives increases (Merbecks, 2024).

While many PHA have moved beyond the initial digitization phase, complete digital transformation remains an ongoing process (Eymann et al., 2024; Merbecks, 2024). As digitalization accelerates, DR will be critical in ensuring that ethical, participatory, and sustainability-oriented considerations are embedded into PHA digitalization efforts. As in Germany these efforts are guided by the PHAMM, it provides a valuable foundation for understanding how digitalization unfolds in this sector. Although the PHAMM was developed including many different stakeholders and their perspective on the need of the PHS within the digitalization process, the PHAMM was not explicitly designed to incorporate ethical, participatory, and sustainability-oriented considerations for ensuring responsible digitalization. To address challenges such as equity in digital access, transparency in decision-making, and trust, DR principles should complement the PHAMM. By examining the PHAMM and the digitalization of the German PHS, this study provides a unique opportunity to contextualize DR principles within a non-company context and adopt a comprehensive ecosystem perspective. It explores PHS-specific needs and assesses how they are reflected within the DR framework.

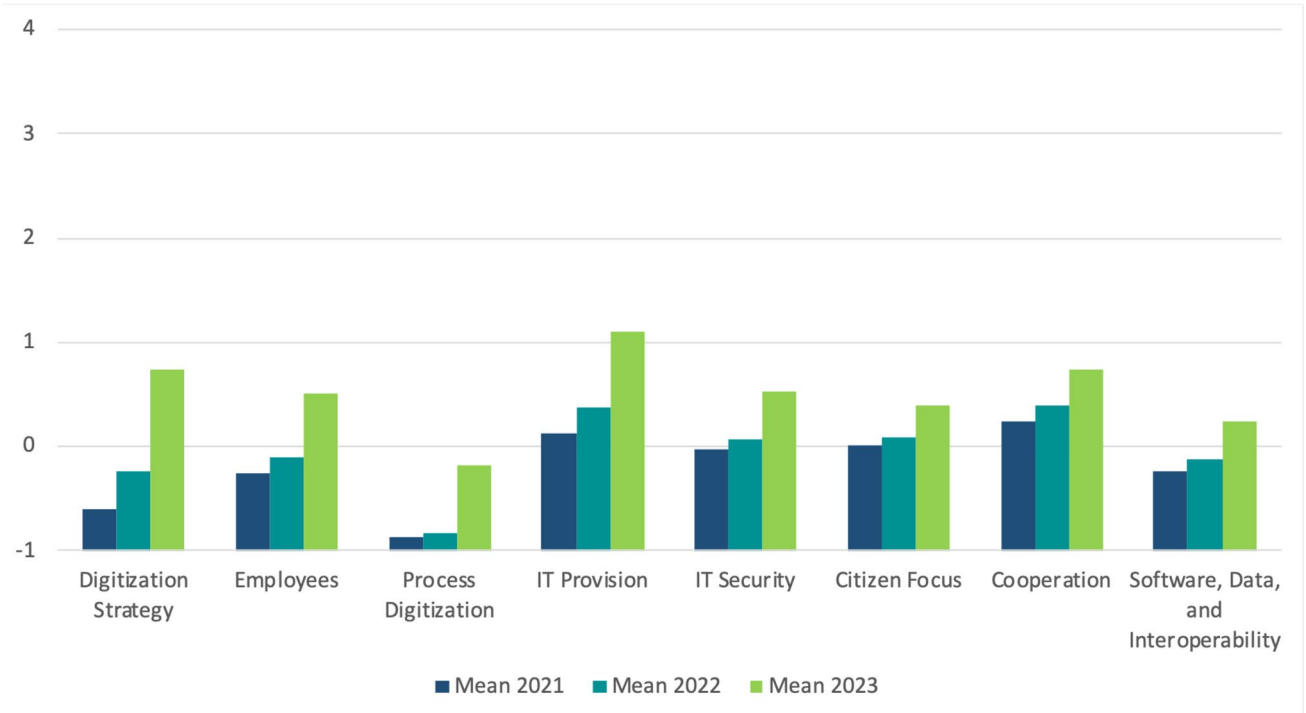

Fig. 2 Self-Assessment results from PHA at the evaluation dates 31. December 2021, 2022, and 2023 (adapted from Eymann et al., 2024)

Content analysis of the PHAMM criteria

To contextualize DR and assess the current realization of the DR framework (Trier et al., 2023), we applied a content analysis to all PHAMM criteria. Following the content analysis by Mayring (2015), two authors conducted the coding of the criteria. Before coding, categories (levels and principles) and their definitions were retrieved from the DR framework by Trier et al. (2023). To achieve a common understanding, the coders discussed the definitions of these predefined categories and collaboratively coded the first 10 PHAMM criteria. Then, both coders coded all PHAMM criteria independently and deductively.

These predefined categories were then complemented through inductive coding, incorporating additional categories derived from the PHAMM criteria not yet represented in the DR framework. During the deductive phase, the two coders recognized the need to introduce two new levels and one additional principle. The two new levels were named Inter- and Intraorganizational. The Interorganizational level relates to cooperation or coordination between organizations, such as PHA collaborating with external entities like hospitals. The Intraorganizational level addresses actions between units of the same organization. Additionally, the coders introduced Security as a new DR principle to account for criteria addressing IT resilience, incident response, and cybersecurity. Subsequent to alignment concerning the two new levels and the additional principle and agreeing on a definition, the coders continued to code the 354 criteria independently.

Some criteria were assigned to several DR principles and levels during this coding process. Only three criteria were not assigned a code for a principle, while a level could be applied to all criteria. Each criterion was assigned up to three levels ($M = 1.29$, $SD = 0.46$) and up to four principles ($M = 1.68$, $SD = 0.75$), demonstrating that DR aspects can be applied to nearly all PHAMM criteria and that multiple aspects of DR can influence a single criterion. For example, the first criterion (DS.1.0.01—A digitalization strategy exists for the public health department or is at least being planned […]) was assigned to the Corporate level because it applies to the organization. In addition, it was assigned to the principles of Transparency and Accountability, as the strategy enhances transparency through clear communication and reinforces accountability through a commitment to digitalization goals. Table 3 provides coding examples to give insight into the coding process. All criteria can be found in the Appendix Part 2.

The intercoder agreement after the independent coding was 63.65% overall. At 77.37%, the agreement for the five levels was notably higher, while for the nine principles, it was lower at 52.87%, indicating that coding was easier for the levels than for the principles. Table 4 shows the total intercoder agreement, also reported separately for each level and principle. The intercoder agreement varied strongly between the codes, highlighting how straightforward or challenging it was to assign the codes. The newly introduced Security principle achieved an exceptionally high level of agreement. However, there were greater difficulties with the principles of Fairness, Norms & Values (each with 0% intercoder agreement), Transparency, and Sustainability.

The Cohen's kappa (calculated by the software MaxQDA; VERBI Software, 2021), according to Brennan and Prediger (1981), is an alternative measurement of intercoder agreement. It is a widely used index that considers the number of categories and agreements by chance and is suitable for two coders with nominal codes. For the overall analysis, Cohen's kappa is 0.61, which is considered a substantial intercoder agreement (Landis & Koch, 1977) and reflects that the result of categorization was not only a matter of chance. The interrater agreement across all levels is substantial, while for all principles it is moderate.

After the first independent coding, the two coders independently reviewed the codes for each criterion that did not receive agreement. They then collaborated to reach a consensus on remaining non-matches, achieving 100% agreement at the end of the coding process. In instances where intercoder agreement was lacking, a structured discussion process was conducted,

Table 3 Coding examples

Criteria	Levels	Principles
BZ.2.1.01—An alternative channel for "non-digital citizens" allows sufficient communication with the public health department	Corporate Level Societal Level	Participation
IB.4.3.01—An IT service management system for sustainable root cause analysis and troubleshooting has been established	Corporate Level	Accountability Functionality Security Sustainability
IB.3.1.02—There is structured coordination between the person responsible for IT, the organizational units of the public health department, and external IT managers or IT service providers	Corporate Level Interorganizational Level Intraorganizational Level	Accountability Transparency
DS.3.2.01—The person responsible for the budget is in close contact with those responsible at the associated or higher-level authority and applies for the budget required for digitization measures (per year)	Interorganizational Level	Accountability

Table 4 Degree of intercoder agreement of both coders before finding consent

Code	Total number of codes	Intercoder agreement as percentage	Kappa for only one code	Meaning of Kappa according to (Landis & Koch, 1977)
DR Level: Corporate Level	602	87.71	0.84	almost perfect agreement
DR Level: Interorganizational Level	74	54.05	0.39	fair agreement
DR Level: Intraorganizational Level	14	0.00	−0.33	no agreement
DR Level: Personal Level	82	53.66	0.38	fair agreement
DR Level: Societal Level	63	53.97	0.39	fair agreement
DR Level: Total	835	77.37	0.74	substantial agreement
DR Principle: Accountability	243	53.50	0.38	fair agreement
DR Principle: Data Privacy	26	69.23	0.59	moderate agreement
DR Principle: Fairness	17	0.00	−0.33	no agreement
DR Principle: Functionality	335	63.28	0.51	moderate agreement
DR Principle: Norms & Values	6	0.00	−0.33	no agreement
DR Principle: Participation	91	48.35	0.31	fair agreement
DR Principle: Security	156	82.05	0.76	substantial agreement
DR Principle: Sustainability	77	10.39	−0.19	poor agreement
DR Principle: Transparency	112	19.64	−0.07	poor agreement
DR Principle: Total	1063	52.87	0.47	moderate agreement
Total of all Codes	1898	63.65	0.61	substantial agreement

which involved reviewing the coding rationale, considering alternative interpretations of definitions, and reaching a consensus on the most appropriate categorization. Ensuring complete agreement was crucial to enhancing the consistency and reliability of the dataset. A lack of agreement could indicate potential subjectivity in coding, which might affect the validity of the findings. By reaching a consensus, the objectivity of the outcomes was strengthened, creating a robust dataset that serves as a reliable foundation for further data analysis.

Upon establishing the final set of codes and corresponding definitions, we situate the principles and levels within their broader context to elucidate themes pertinent to the PHS. For this contextualization, two researchers independently categorized all criteria within each level/principle into subcategories. In the final step, a third researcher reviewed the subcategories to ensure consistency and resolve discrepancies. Inconsistencies were discussed and resolved, resulting in a final set of contextualized principles and subcategories, including their definition.

Validation of findings with an online focus group with experts

To validate and refine the results from the content analysis, we conducted an online focus group (Nyumba et al., 2018) comprising researchers and practitioners in the field of maturity models, DR, and/or PHS. This methodological triangulation ensures that the proposed adaptations to the DR framework are theoretically plausible, practically meaningful, and grounded in domain expertise. Participants were selected from different organizations to capture diverse perspectives. After sending invites to 21 experts, nine agreed and participated in the focus group. Four participants were practitioners in various positions of the PHS, four had a maturity model and digitalization background, and one had expertise in DR. Six participants were male, and three were female. Participants received information about the focus group and a consent and data privacy form, which they were asked to sign and return before participation. The session was conducted using video conferencing and a digital whiteboard (see Appendix Part 1) to facilitate collaboration.

The focus group followed a structured process: First, two authors introduced the purpose of the focus group, the DR framework, and the PHAMM. Second, an introduction to the digital whiteboard was given. Third, experts brainstormed the importance of DR principles and levels for the PHA. Lastly, participants discussed DR principles and levels and their significance for PHA. The whole process was moderated by two authors and recorded. In total, the focus group lasted 85 min. Participants shared their assessments and opinions using the whiteboard and the discussion, leading to 69 comments on levels and principles and 16 comments on four additional questions, focusing on practical implications and the challenges and opportunities of the findings for the PHA. The recordings of the focus group were transcribed. Whiteboard comments and the transcript were then analyzed using the thematic analysis method, according to Braun and Clarke (2006). Two coders coded all relevant extracts in the material thematically. Then, the

codes were assigned to sub-headers, constructed by the coders for similar topics.

Results

Content analysis

Digital responsibility in the PHAMM

This section focuses on how DR is reflected across the PHAMM dimensions (RQ1). Table 5 shows how often each code was used in the final consented version. For example, the number 325 for the Corporate level in row one of Table 5 indicates that 325 criteria were coded with this label, representing 91.8% of the total criteria. This represents the highest number of codes, which points to the PHAMM being explicitly designed to drive organizational changes (Doctor et al., 2023).

The second and third most frequently applied codes were Functionality and Accountability, highlighting PHAMM's focus on improving the performance of the PHA and establishing clear responsibilities. In contrast, Fairness was assigned very few times, indicating that this aspect has received little attention in PHAMM. Yet, some aspects that could fall under Fairness, such as barrier-free accessibility, were assigned to Participation instead. Norms & Values also posed challenges, as many aspects that could be considered as Norms & Values, such as Transparency, Sustainability, and Fairness, are separate principles. Only one criterion represented an additional norm or value, related to lifelong education, that could not be categorized under the other principles. Such observations show how various DR elements converge to influence single organizational practices. Table 6 presents the codes according to the eight PHAMM dimensions.

Table 5 Number of codes in the final, consented version

Code	Total number of criteria with this code	Percentage of all criteria
DR Level: Corporate Level	325	91.8
DR Level: Interorganizational Level	40	11.3
DR Level: Intraorganizational Level	14	4.0
DR Level: Personal Level	59	16.7
DR Level: Societal Level	20	5.6
DR Level: Total	458	/
DR Principle: Security	84	23.7
DR Principle: Data Privacy	12	3.4
DR Principle: Functionality	194	54.8
DR Principle: Accountability	133	37.6
DR Principle: Participation	57	16.1
DR Principle: Transparency	76	21.5
DR Principle: Sustainability	32	9.0
DR Principle: Fairness	4	1.1
DR Principle: Norms & Values	1	0.3
DR Principle: Total	593	/
Total of all Codes	1051	/

Table 6 Overview of the eight PHAMM dimensions and the percentage of their respective criteria assigned to the five DR levels and nine DR principles

	Dimension: Digitalization strategy	Dimension: Employees	Dimension: Process digitalization	Dimension: IT Provision	Dimension: IT Security	Dimension: Citizen Focus	Dimension: Cooperation	Dimension: Software, Data and Interoperability
DR-Level: Corporate	77,4	93,0	97,2	100,0	97,3	100,0	51,6	98,3
DR-Level: Interorganiszational	32,3	7,0	2,8	9,4	4,0	0,0	35,5	10,3
DR-Level: Intraorganizational	6,5	0,0	0,0	3,1	0,0	0,0	32,3	0,0
DR-Level: Personal	3,2	72,1	8,3	25,0	8,0	0,0	0,0	3,4
DR-Level: Societal	3,2	0,0	0,0	0,0	0,0	100,0	0,0	5,2
DR-Principle: Accountability	71,0	20,9	44,4	34,4	62,7	6,3	16,1	19,0
DR-Principle: Data Privacy	0,0	7,0	0,0	1,6	0,0	0,0	0,0	13,8
DR-Principle: Fairness	6,5	2,3	0,0	0,0	0,0	6,3	0,0	0,0
DR-Principle: Functionality	38,7	20,9	41,7	67,2	44,0	62,5	83,9	79,3
DR-Principle: Norms & Values	0,0	2,3	0,0	0,0	0,0	0,0	0,0	0,0
DR-Principle: Participation	3,2	83,7	0,0	4,7	9,3	37,5	9,7	1,7
DR-Principle: Security	3,2	4,7	0,0	12,5	92,0	6,3	0,0	5,2
DR-Principle: Sustainability	6,5	11,6	13,9	14,1	0,0	12,5	16,1	6,9
DR-Principle: Transparency	38,7	23,3	55,6	9,4	17,3	31,3	9,7	12,1
Total number of criteria in the PHAMM dimension	31	43	36	64	75	16	31	58

Most IT Security PHAMM dimension criteria were assigned to Security (92%). Similarly, most of the codes in the Employees PHAMM dimension were linked to the Personal level (72%) and the Participation principle (83.7%). Also, 100% of the Citizen Focus PHAMM dimension was assigned to the Societal level. The Interorganizational level is most frequently used in the Cooperation dimension, which includes a subdimension for cooperation with higher-level authorities and external stakeholders. Data Privacy was mainly applied to the Data, Software, and Interoperability PHAMM dimension.

Building on the results in Tables 5 and 6, Fig. 3 provides a visual overview of the distribution of criteria across DR levels and principles. Each black-framed rectangle represents a DR level, with its size proportional to the number of criteria assigned. The colored blocks within these rectangles indicate the principles, highlighting their distribution across the respective levels. For example, the Corporate level, with the largest black-framed rectangle, accounts for 91.8% of all criteria. Within the Corporate level, Functionality (beige) and Accountability (brown) dominate, ensuring operational efficiency and defined responsibilities. In contrast, Participation (red) is primarily represented within the Personal level, highlighting the focus on engaging individuals in digitalization. Security (orange) appears across multiple levels, emphasizing its role in maintaining data protection, system resilience, and secure processes. The tree map also highlights principles that are underrepresented across the levels. For instance, Fairness (blue) and Norms & Values (pink) represent only a few PHAMM criteria, indicating that these DR aspects are less prominent within the PHAMM.

Contextualizing the DR principles

The categorization of the assigned PHAMM criteria resulted in one to five subcategories for each contextualized DR principle. Seven principles feature up to five subcategories, while one principle includes two, and one principle has a single subcategory. Below, we outline the categories for each DR principle, arranged in order of the allocated PHAMM criteria.

1. Functionality: This DR principle comprises 194 criteria. It focuses on strategic planning, evaluation, and execution of PHA digitalization. It is structured into five subcategories. The first, Digitalization Strategy and Implementation, emphasizes that digital processes

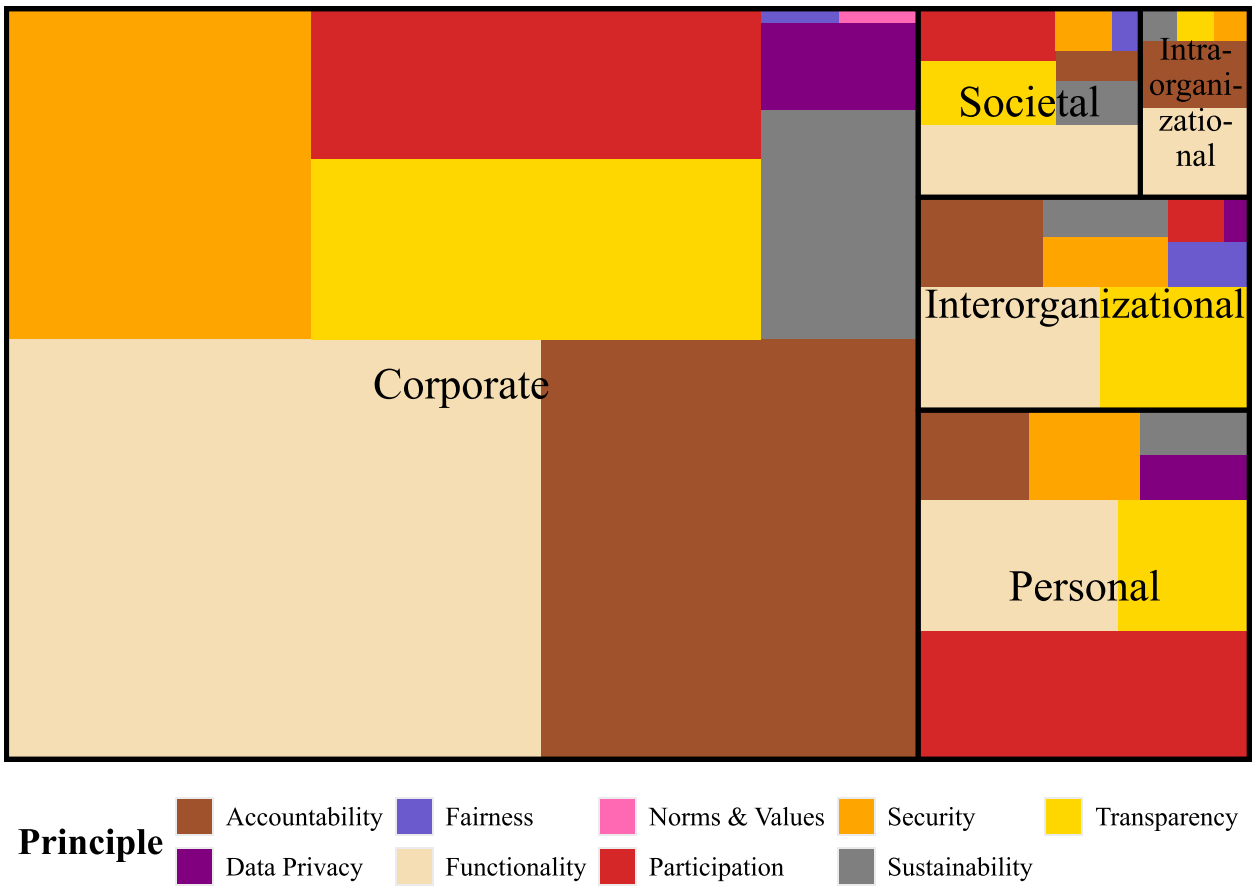

Fig. 3 Treemap illustrating criteria distribution across DR levels and principles: Black frames represent levels, colors represent principles, and block size reflects the number of criteria assigned

should be regularly reviewed, adjusted, and supported through clear digitalization goals, roadmaps, and assigned responsibilities within PHA and in collaboration with other agencies. A second subcategory, Competency and Training, highlights that digital transformation requires employees to acquire and develop the necessary expertise. Such competencies are essential for staff proficiency and embedding digital literacy into training and onboarding. User-Centered Processes and Systems prioritize usability, adapting tools to meet user needs. Interfaces and Data Integration streamline workflows by optimizing IT systems and minimizing redundant data entry. For example, an online portal can allow citizens to book appointments intuitively. Finally, the Evaluation and Optimization of Specialized Applications involve regular assessments for performance, accessibility, and data protection compliance, with feedback loops for continuous improvement.

2. Accountability: This principle, supported by 133 criteria, is essential for well-coordinated and effectively managed PHA digitalization efforts. It establishes clear responsibilities, ensures transparency in decision-making processes, and guarantees the efficient use of resources. It includes five subcategories. Strategy and Planning ensure that digital strategies are defined, documented, and reviewed to meet current and future goals. Responsibilities and Authorities assign roles for digitalization initiatives, designating contacts and leaders to ensure accountability. A digitalization officer, for example, can be assigned within the PHA to coordinate digitalization projects and act as a central interface between IT and administration. Regular Evaluation and Control ensure that digitalization measures are effective and aligned with the organization's strategic goals. Resource Management focuses on budgeting and resource allocation, prioritizing initiatives based on strategic importance. Finally, Documentation and Transparency emphasize standardized documentation to ensure clarity and trust. In practice, this documentation includes training concepts, IT security guidelines, and technical documentation for specialist applications that arise during digitalization projects.
3. Security: With 84 criteria, this principle is vital for safeguarding IT systems and sensitive data in public health digitalization. It ensures that PHA remains resilient to threats, that security incidents are quickly detected and resolved, and that employees are continuously aware of IT security risks. It includes five subcategories. IT Security Concepts and Processes involve developing and updating security frameworks, including risk management and reporting. Employees play a central role in IT security. Accordingly, Training and Awareness programs provide mandatory sessions to inform staff about current security protocols and emerging threats. Efficient Incident Management and Response Processes ensure quick action during security breaches through defined reporting and response channels. Security Infrastructure and Monitoring deploy tools like malware scanners and real-time monitoring systems for early threat detection. Finally, Access and Authorization Management involves setting, reviewing, and adjusting access rights to prevent unauthorized access to sensitive systems. In practice, role-based access controls ensure that employees can only access the data they need for their work.
4. Transparency: This principle, with 76 criteria, is essential for openness and clarity in public health digitalization. Transparency ensures that both internal processes and external services are understandable and accessible. It includes five subcategories. Strategy Documentation and Availability ensure that digitalization strategies are documented and accessible. Information Exchange and Communication foster regular dialogue across PHA, employees, and stakeholders to support communication and collaborative adjustments to digital measures. Process Documentation and Traceability establish a clear, traceable workflow structure through standardized modeling languages and IT systems. IT Security Reports and Guidelines update employees on security measures and contacts, enhancing transparency. Lastly, Citizen-Oriented Information Provision provides regular updates and accessible online services, e.g., on vaccination campaigns and digital registration systems.
5. Participation: This principle, with 57 criteria, emphasizes the active engagement of employees and citizens in digital PHA efforts. Participation ensures that digitalization processes are not only controlled top-down but are continuously improved through practitioners' and citizens' feedback. It includes five subcategories. Involvement in Digitalization Measures encourages employees to actively participate in developing and implementing digital initiatives, with opportunities for input. Opportunities for Participation and Feedback provide channels for employees to share feedback and contribute to application improvements. Inclusion and Diversity in Digitalization Processes ensure that projects consider diverse backgrounds and age groups, with ongoing dialogue with employee committees. For example, when introducing an e-learning system, efforts are made to ensure the content is fully accessible and offered in multiple languages. Training and Education equip staff with the skills needed for digital involvement, focusing on IT security, applications, and collaboration. Finally, Citizen Participation addresses public needs and preferences in digital health, ensuring accessible and inclusive services for all citizens.

6. Sustainability: This principle, with 32 criteria, emphasizes the long-term viability of digitalization in public health. The aim is to design digital solutions in such a way that they not only work in the short term but also respond to future challenges and thus remain economically viable. It includes five subcategories. Resource Management and Support provide financial and organizational aid to help less digitally mature PHA implement sustainable digital initiatives. For example, federal funding programs provide funds for IT infrastructure development. Ergonomics and Work Environment ensure workspaces with ergonomic setups and appropriate IT resources to avoid absences due to illness. Flexible and Modular IT Infrastructure enables adaptable IT systems that respond quickly to crises and evolving demands. Process Evaluation and Continuous Improvement focus on regular reviews to enhance efficiency and contribute to long-term sustainability. Lastly, User-Centered and Modular Solutions deliver flexible, sustainable digital tools to meet user needs.
7. Data Privacy: With 12 criteria and five subcategories, this principle centers on protecting personal data in public health. A comprehensive data protection concept is essential, since PHA daily works with highly sensitive health data, such as illness reports and laboratory results daily. Training and Awareness programs provide mandatory sessions to cultivate data protection and build an understanding of GDPR requirements. Anonymization and Pseudonymization methods secure sensitive information and show adherence to legal regulations. Legal Compliance and Implementation keep privacy processes updated to meet changing regulations. Finally, the Exchange on Data Privacy Regulations promotes collaboration among PHA to share best practices and strengthen data privacy.
8. Fairness: This principle is supported by four criteria and two subcategories. Fairness in digitalization signifies that neither PHA nor citizens should be marginalized by digital transformation. It emphasizes Support for Other Health Authorities by aiding those with lower digital maturity through targeted measures such as workshops and consultations. Accessibility to ensure digital health services underscores the importance of making digital health services accessible to all citizens to promote equal opportunities for participation.
9. Norms & Values: This principle, with only one criterion and one subcategory, focuses on Promoting a Digital Learning Culture by creating an environment where the continuous development of employees' digital skills is encouraged. In this context, PHA managers are pivotal in advocating digital transformation and guaranteeing adequate staff training and capacity development resources.

Contextualizing the DR levels

In applying the DR framework to public health, we identified all DR levels from Trier et al. (2023) as relevant. The PHAMM criteria were most frequently assigned at the Corporate level, highlighting how the framework aligns with the organizational hierarchy. To fully address the unique needs of public health, we found it necessary to introduce two additional levels: the Intra- and Interorganizational levels. Analogous to the DR principles, we categorized the DR levels using the allocated PHAMM criteria.

1. Corporate: This level, supported by 325 criteria, defines key roles and responsibilities within the organizational hierarchy for public health digitalization. It includes five subcategories. Top Management is responsible for setting the digitalization strategy, ensuring alignment with the organization's long-term goals, and responding quickly to the dynamic healthcare environment when needed (Kokol et al., 2022). Middle Management coordinates and monitors implementation, conducting evaluations and translating the strategy into actionable plans for each unit (Odone et al., 2019). Operational Leadership and Coordination manages department-level digital projects, working with staff to ensure steady project progress.
2. Personal: This level, with 59 criteria, focuses on the role of individual employees in public health digitalization. It includes five subcategories. Individual Relevance assesses how well employees understand their roles in digitalization. Involvement and Influence focus on opportunities for employees to shape digital processes essential for effective implementation (O'Connor et al., 2016). Awareness Building raises understanding of digitalization, data protection, and IT security, fostering a mindful approach to digital practices, as highlighted by Scholl (2018). Implementation Capability ensures that employees can apply knowledge from training in daily tasks, which is essential for IT security (Hepp et al., 2018). Assuming Responsibility emphasizes IT security and data protection accountability, encouraging the follow-up of best practices.
3. Interorganizational: This newly introduced level, with 40 criteria, emphasizes collaboration and coordination among PHA and external stakeholders. It includes four subcategories. Collaboration between Health Authorities promotes knowledge-sharing and joint progress on digital initiatives across health departments. Coordination with Higher Authorities aligns IT infrastructure, security, and budgets with oversight agencies. External Stakeholder Communication fosters partnerships with hospitals and research institutions through digital chan-

nels. Finally, Cross-Institutional Data Exchange supports data and knowledge sharing.

4. Societal: With 20 criteria, this level addresses broader societal impact. It includes five subcategories. The Political Level covers federal and state regulations that PHA must integrate into their digital strategies, ensuring compliance with legal frameworks and alignment with societal goals, as indicated by Jarrin and Parakh (2021). Citizen and Population focuses on communication between PHA and citizens, emphasizing digital contact options, seamless communication, and online consultations to meet public needs. For Non-Digital Population Groups, alternative communication channels should be ensured to reach those without digital access. Science and Research promote data-sharing for public health research to enable timely responses to health challenges, as highlighted by Walport and Brest (2011). Finally, Economy and Technology Providers are involved in integrating external solutions.
5. Intraorganizational: This newly introduced level, with 14 criteria, focuses on the internal dynamics of digitalization within PHA. It includes five subcategories. Department Leadership involves employees in planning and implementing digitalization initiatives. In line with that, Mac McCullough et al. (2020) show that strong relational coordination among department staff is essential for successful digital project implementation. Department-Management Coordination ensures structured feedback channels for ongoing digital projects. Internal Department Coordination promotes a communication structure and, as mentioned by Valaitis et al. (2018), also facilitates inclusion and diversity within projects. Technical Support provides tailored training and IT infrastructure to support digital initiatives. Finally, Cross-Departmental Collaboration facilitates seamless data exchange and IT-supported processes across departments.

Focus group insights on the extended and contextualized DR framework

The results presented in this section are based on the qualitative insight from the focus group. They do not claim to be representative but serve to illustrate key arguments in favor of or against specific aspects found in the content analysis. The following paragraph summarizes the relevant themes that emerged during the discussion, including perceptions of individual principles and levels, their applicability in the PHS, and suggestions for refining the DR framework:

Distinctiveness and Clarity of Principle: A key topic was the lack of differentiation between the existing principles, particularly Norms & Values, which experts regarded as broad and abstract. It was perceived more as an umbrella category under which principles such as Transparency and Fairness could also fall. It was noted that Norms & Values serves as a placeholder for values not explicitly captured by the other principles.

Perceived Relevance of Specific Principles: The perceived relevance of the principles varied. The experts mentioned that Participation, Transparency, and Data Privacy are relevant to the PHS. Also, experts evaluated the new Security principle as an appropriate, distinct, and important addition to Data Privacy, as it points out the importance of IT security efforts in the PHS and is in line with former literature, according to the experts. In contrast, some considered Norms & Values foundational, while others questioned their practical relevance. One participant remarked: “I think Norms & Values are unfortunately the last thing they will look at because it's really about the core things that they have to drive forward with very, very few resources, which are not increasing.”

Relationship between Principles and Levels: A notable insight emerged regarding the interplay between DR principles and levels. Experts pointed out that the meaning of some principles can vary depending on the level at which they are applied. For example, Transparency may imply open communication and clear service information for citizens, while for organizations, it refers more to algorithmic explainability or internal decision-making processes.

Relevance of (New) DR Levels: The newly proposed Inter- and Intraorganizational levels elicited mixed reactions. Some experts pointed out that PHA often collaborate closely with municipal structures, making it difficult to separate the levels. Others criticized that the terms primarily describe relational dynamics rather than distinct responsibility structures, which had been a strength of the original DR levels. However, a more in-depth discussion led to a shared understanding that these additional levels can offer valuable orientation in the context of PHA, particularly in identifying potential actors responsible for implementing DR. In contrast, for reflecting insight into DR, the conversation also revealed that instead of expanding the number of equally ranked levels, it may be more helpful to distinguish between levels of responsibility and the relationships across these levels, such as Inter- and Intraorganizational dynamics.

Integration of DR into the PHAMM: The focus group also touched on the integration of DR into the PHAMM. There was a consensus that aligning DR principles with PHAMM dimensions could support more ethically grounded digital transformation processes in PHA. Some experts noted that DR principles should be integrated into different PHAMM levels, with the (regulatory) required and fundamental principles needed within the lower PHAMM levels and more aspirational DR principles like Norms & Values in higher PHAMM levels.

Need for Standardization and Regulatory Anchoring: Participants emphasized the importance of explicitly integrating standards, such as interoperability, into the DR framework. Generally, a broader call for more regulatory or top-down mechanisms to support the implementation of DR was linked, in line with arguments by van der Merwe and Al Achkar (2023).

Discussion

This paper combined a content analysis with a focus group and pursued two objectives. First, it contextualizes DR within public health and examines responsible digitalization within PHA (RQ1), including the representation of DR principles in the PHAMM. Second, it refines the DR framework by proposing meaningful extensions based on the key insights (RQ2). The following two subsections analyze the alignment between PHAMM and DR and propose a contextualization of DR principles and levels tailored to the specific needs of public health (RQ1). The third subsection discusses refinements to the DR framework based on the findings (RQ2). The fourth subsection summarizes lessons learned derived from this study.

DR in the PHAMM: Mapping principles and levels

This study shows that although the PHAMM was not designed to align with the DR framework, it inherently incorporates several DR principles. This implicit alignment may stem from public health's normative focus on accessibility, inclusion, and accountability. The content analysis highlights the strong presence of Functionality, Accountability, Transparency, Participation, and Security, each reflected in numerous PHAMM criteria. These findings were largely supported by the focus group participants, who emphasized that aspects of responsible digitalization are already implicitly embedded within the PHAMM. Yet, they also noted that these principles are not systematically anchored or made visible, suggesting that the PHAMM could benefit from more explicit integration of DR concepts. Moreover, some principles highlighted by experts as necessary are not yet broadly integrated into the PHAMM, such as Data Privacy and Fairness.

The content analysis further revealed that Fairness and Norms & Values were underrepresented in the PHAMM and were the only principles with an intercoder agreement of 0%. This underrepresentation was also a central topic in the focus group discussion. While Fairness was considered highly relevant in practice — ensuring equal access, avoiding discrimination, and minimizing bias in IT-based decision-making — its lack of systematic embedding in PHAMM reveals a design gap. In contrast, PHA experts found Norms & Values to be too abstract. They emphasized the need for more precise definitions or explicit linkages to sector-specific values such as solidarity or health equity. A DR expert in the focus group further argued that Norms & Values serves as a residual category, hosting issues not captured by other principles. This residual character provides a plausible explanation for both the low intercoder agreement and the limited attribution to PHAMM criteria, as this conceptual role was not apparent to the coders then. These findings suggest that Fairness highlights a design limitation of PHAMM, whereas Norms & Values point to a conceptual gap in the DR framework that warrants further theoretical refinement.

Furthermore, the content analysis identified Security as a new DR principle that, while not part of the original DR framework, is essential in public health. While Data Privacy is included, broader technical and operational measures to protect IT systems from cyber threats are an urgent concern, given the public health's reliance on sensitive health data and its crucial role in pandemic and emergency management. Ensuring system resilience against security breaches or cyberattacks is fundamental for maintaining the functionality of PHA (Kandasamy et al., 2022; Puri & Gochhait, 2023). The relevance of Security was validated by focus group participants, who considered it foundational for enabling digital trust and ensuring the continuity of public health operations. They emphasized that Data Privacy, while necessary, represents the entity to be protected. However, it lacks the operational and technical aspects required to safeguard this data within PHA, making Security a valuable addition as a distinct DR principle.

Two additional DR levels, Intra- and Interorganizational, were introduced to better reflect the structural realities of public health governance. These levels address a gap in the DR framework by recognizing the importance of internal coordination and cross-institutional partnerships, particularly in areas such as data sharing and joint resource planning. Public health experts in the focus group welcomed these additions, noting that they reflect the interconnected and multiple-actor nature of PHA delivery. However, the discussion further revealed that while the two new levels improve the understanding of the dynamics within the PHA, the existing DR levels (e.g., Personal, Corporate, Societal) already capture the distinct structures where responsibility resides. Intra- and Interorganizational aspects can instead be seen as descriptions of how responsibility is distributed and coordinated within or across these established levels.

According to the content analysis, the Corporate level emerges as the most prominent, underscoring its central role in driving organizational change and digitalization within PHA. In contrast, the Societal and Intraorganizational levels are less prominent, suggesting a lack of attention to broader societal impacts and cross-departmental collaboration in the PHAMM. The focus on the Corporate level aligns with

prior DR research, which has predominantly adopted a CDR perspective (Trier et al., 2023; van der Merwe & Al Achkar, 2022). Yet, focus group participants warned that neglecting the other levels could undermine digital transformation efforts' long-term legitimacy and effectiveness, underscoring the need for deeper integration into PHAMM. Such concerns align with the DR implementation guidelines (Herden et al., 2021), which propose a five-step process for operationalizing DR: (1) perform self-assessment, (2) develop a vision, (3) identify the gaps, (4) close the gaps, and (5) ensure their closure over time. This study and the DR framework (as the vision) address steps 1 to 3. To further foster DR in the PHS, steps 4 and 5 should be addressed in the future, and DR principles and levels not yet profoundly covered in the PHAMM could be elaborated and incorporated.

Beyond these implementation aspects, it is also important to consider how DR is positioned within the broader digital transformation process. Merbecks (2024) positions (C)DR within the later stage of digital transformation rather than in earlier phases of the digital journey, such as digitization and digitalization. Yet, the content analysis indicates that criteria across all levels of the PHAMM can be associated with the DR framework. Moreover, the focus group discussion confirmed that DR encompasses "voluntary" aspects at higher PHAMM levels and regulated elements, such as Data Privacy, already embedded at lower levels. Conversely, currently, non-regulated or voluntary aspects of DR may, over time, become subject to legal requirements and should then be integrated into lower PHAMM levels. This perspective challenges Merbeck's (2024) narrower view and suggests that DR is not limited to a specific digital journey stage but spans the entire journey. This broader positioning of DR aligns with recent debates that emphasize its cross-cutting relevance for digital governance rather than restricting it to a specific stage of transformation. In particular, Herden et al. (2021) conceptualize DR as a continuous implementation process across different steps, while Trier et al. (2023) frame DR as a governance lens with principles and levels applicable throughout the digital transformation journey.

Validating and refining the DR framework within the PHS context

Some alignments between DR principles and PHAMM dimensions may seem self-evident, such as the frequent assignment of Functionality to Corporate-level criteria or the association of the Cooperation dimension with the Interorganizational level. These patterns validate the applicability of the DR framework in public health by confirming that it captures essential structures and goals of digital transformation. At the same time, according to the experts, the framework's strength lies in revealing conceptual mismatch or underrepresentation, such as the low prominence of Data Privacy, Fairness, or Norms & Values, despite their importance within the PHS. This combination of expected alignments and surprising gaps provides a foundation for adapting the DR framework to the public health sector and for further advancing the framework itself. Both aspects are discussed in the following section.

DR in public health: Contextualization and application

The contextualization of DR principles and levels for public health offers insights that bridge the gap between mere theoretical frameworks and the real-world application of DR (Trittin-Ulbrich et al., 2025), thus synergistically addressing the need for context-specific approaches to DR (Carl & Hinz, 2024). Table 7 outlines the contextualized DR principles, depicting subcategories for each DR principle, thus emphasizing their specific relevance and interpretation within PHA. For instance, the **Functionality** principle includes digitalization strategies, competency development, and user-centered processes — all critical for enhancing operational efficiency in PHA. Likewise, **Accountability** highlights the importance of strategic planning and transparent documentation, both of which are essential for managing complex public health initiatives.

Importantly, while some categories are unique to the PHS (e.g., support for other health authorities), many should be broadly applicable across various contexts, such as education or public administration, where digital transformation is also increasingly vital (e.g., Kuhlmann & Heuberger, 2023). To facilitate cross-sectoral applicability, the categories specific to public health are marked with an asterisk (*), allowing the distinguish between generalizable insights and those that are uniquely relevant to public health. For example, Kuhlmann and Bogumil (2021) emphasize the need for uniform standards in authentic data sources and equitable citizen treatment to enhance the digital maturity of local governments. Therefore, greater attention should be given to documentation and transparency in municipal digitization efforts.

Additionally, Table 8 summarizes the contextualization of the DR levels, including subcategories for each DR level. Analogous to the DR principles, categories that are specific to public health are marked with an asterisk (*). For example, the Corporate level emphasizes top management strategies and cross-departmental collaboration, while the Interorganizational level highlights the importance of partnerships with external stakeholders such as hospitals and research institutions. Most of these levels are transferable and relevant to other (local) public services, particularly the Interorganizational level. In a federal system, stronger collaboration and coordination with various stakeholders are essential to ensure the compatibility of different local digital solutions (Kuhlmann & Bogumil, 2021).

Table 7 Contextualizing DR Principles: Subcategories for DR Principles; (*) = public health specific

Principle	1. Subcategory	2. Subcategory	3. Subcategory	4. Subcategory	5. Subcategory
Functionality (194 criteria)	Digitalization Strategy and Implementation to plan and evaluate the digital strategy.	Competency and Training to enhance staff skills including training and onboarding programs.	User-Centered Processes and Systems to improve usability and adapt systems to user needs.	Interfaces and Data Integration to ensure smooth workflows and eliminate redundant data entry.	Evaluation and Optimization of Specialized Applications for, e.g., performance and accessibility.
Accountability (133 criteria)	Strategy and Planning to set digital strategies, target states, and regular reviews.	Responsibilities and Authorities to assign clear roles and designate contacts.	Evaluation and Control to assess processes and strategies.	Resource Management to allocate budgets and prioritize measures.	Documentation and Transparency to ensure transparent implementation with standardized documentation.
Security (84 criteria)	IT Security Concepts and Processes to develop and update security frameworks.	Training and Awareness to provide mandatory training on current security protocols.	Incident Management and Response Processes to ensure prompt response to security incidents.	Security Infrastructure and Monitoring to use real-time monitoring and alerts for quick threat detection.	Access and Authorization to define and review access rights to prevent unauthorized access.
Transparency (76 criteria)	Strategy Documentation and Availability to ensure employees access the digitalization strategies.	Information Exchange and Communication to provide regular updates on digital projects.	Process Documentation and Traceability to create a clear structure using standardized languages.	IT Security Reports and Guidelines to keep employees informed about security measures and contacts.	Citizen-Oriented Information Provision (*) to offer updated online information and direct communication channels for citizens.
Participation (57 criteria)	Involvement in Digitalization Measures to engage employees in digital initiatives.	Opportunities for Participation and Feedback to provide channels for employee feedback.	Inclusion and Diversity in Digitalization Processes to include diverse backgrounds and ages.	Training and Education to equip employees with skills for digital participation.	Citizen Participation (*) to address citizens' needs in digital health services, ensuring accessible options.
Sustainability (32 criteria)	Resource Management and Support to aid less digitally mature PHA.	Ergonomics and Work Environment to ensure ergonomic workspaces.	Flexible and Modular IT Infrastructure to enable adaptable IT systems for crisis response.	Process Evaluation and Continuous Improvement to improve efficiency for sustainability.	User-Centered and Modular Solutions to provide flexible, sustainable digital tools.
Data Privacy (12 criteria)	Data Privacy Concept to implement a data privacy framework.	Training and Awareness to provide regular data protection training.	Anonymization and Pseudonymization to protect personal data and ensure compliance.	Legal Compliance and Implementation to keep privacy processes updated.	Exchange on Data Privacy Regulations to promote knowledge-sharing.
Fairness (4 criteria)	Support for other Health Authorities (*) to help other agencies advance in digitalization.	Accessibility to ensure digital health services (*) are usable by all, including with disabilities.	/	/	/
Norms & Values (1 criterion)	Promoting a Digital Learning Culture to support continuous improvement in digital skills.	/	/	/	/

Table 8 Contextualizing DR levels: Subcategories for DR levels; (*) = public health specific

Level	1. Subcategory	2. Subcategory	3. Subcategory	4. Subcategory	5. Subcategory
Corporate Level (325 criteria)	Top Management Level to oversee and finalize digitalization strategy	Middle Management to coordinate, evaluate, and implement actions within the units.	Operational Leadership and Coordination to manage department-level projects.	Cross-Departmental Collaboration to enable smooth, coordinated processes across departments.	Specialized Roles, e.g., to provide technical support in IT infrastructure and cybersecurity.
Personal Level (59 criteria)	Individual Relevance to help employees understand the significance of digitalization for their daily work.	Involvement and Influence to offer employees participation opportunities and influence in shaping digital processes.	Awareness Building around digitalization, data protection, and IT security among individuals.	Implementation Capability to apply acquired knowledge through training and technical resources.	Assuming Responsibility to foster individual accountability in IT security and data protection.
Interorganizational Level (40 criteria)	Collaboration between Health Authorities (*) to share knowledge and support digitalization.	Coordination and Collaboration with Higher-Level Authorities (*) to align IT, security, and budgets.	Communication and Collaboration with External Stakeholders to connect with hospitals and research institutions.	Cross-Institutional Data Exchange to improve data sharing in areas like infection control.	/
Societal Level (20 criteria)	Political Level to align with federal and state regulations.	Citizen and Population to support digital communication and online services.	Non-Digital Groups to provide accessible, non-digital options.	Science and Research to support data sharing.	Economy and Technology to use external solutions to improve efficiency and meet public needs.
Intraorganizational Level (14 criteria)	Department Leadership to plan and oversee digital initiatives within departments.	Department-Management Coordination to enable structured communication across levels.	Internal Department Coordination to manage data exchange and IT-supported communication.	Technical Support to provide tailored IT infrastructure for each department.	Operational Cross-Departmental Collaboration to facilitate data exchange and IT processes across departments.

Through the more detailed description of the levels and principles and the domain-specific definitions, the contextualization provides a basis for translating the rather abstract DR principles into a more practical, real-world- oriented guide. Thus, it can serve as a "method as systematic procedure" (Trittin-Ulbrich et al., 2025, p. 20) supporting public administration, especially PHS, to implement DR.

Evolving the DR framework

The refinement of the DR framework presented in this study, which further complements the contextualization, is based on a systematic mapping of DR principles and levels to the PHAMM, enriched by the focus group feedback. These refinements provide theoretical insights into the DR framework and its current blind spots, highlighting and proposing needed adjustments to guide DR in a complex multilevel and multi-stakeholder environment. The resulting adjustments address three aspects: (1) conceptual rethinking of the DR principle Norms & Values, (2) integration of relational dimensions into the level structure, and (3) introduction of Security as a new DR principle.

1. **Rethinking Norms & Values:** In the focus group, PHA experts expressed concerns about the vagueness of the Norms & Values principle and its conceptual overlap with different principles. This point was elaborated on by the DR expert participant, who explained that Norms & Values function more as a residual category rather than a delineated principle. It was not conceptually defined from the ground up in Trier et al. (2023) but emerged from the aggregation of prior research that emphasized different ethical dimensions. Accordingly, the expert explained that some values, such as Transparency, have gained prominence and institutional recognition, thus justifying their treatment as standalone principles. In contrast, others, such as Well-being or Trust, are equally relevant from an ethical perspective but have not yet reached the same level of codification. As a result, they are currently subsumed under Norms & Values. The expert emphasized that this category is designed to remain open and inclusive, allowing for the incorporation of additional ethical dimensions that may become relevant, thus also accounting for the ongoing evolution of digital technologies (Recker et al., 2025; Trittin-Ulbrich et al., 2025). At the same time, the conceptual fluidity of this category was acknowledged as a limitation, as it complicates the clear demarcation between DR principles. The limited demarcation of the Norms & Values principle and other related principles, such as Transparency and Fairness, explain the poor intercoder agreement reached during the coding process for those principles. This challenge is not unique to our study but reflects a broader debate in DR research. Lewerenz et al. (2025) show that guiding values in digital health are plural, fluid, and difficult to codify consistently, complicating their systematic operationalization. Similar challenges are described by Sikstrom et al. (2022), who demonstrate that while principles such as Transparency and Fairness can be operationalized through defined pillars (e.g., transparency, impartiality, inclusion), other values such as trust or well-being remain ethically significant yet insufficiently codified. These findings underline that Norms & Values embody a conceptual openness that complicates clear demarcation but also allows for the inclusion of emerging ethical concerns. Future research could therefore examine how such principles can be more robustly operationalized in practice — for example, through participatory design approaches or inclusive digital literacy initiatives that explicitly incorporate fairness- and value-oriented perspectives (Lewerenz et al., 2025; Sikstrom et al., 2022).
2. **Rethinking DR Levels:** Another insight concerns the conceptual nature and structure of DR levels. While the initial DR framework focused on distinct levels — Personal, Corporate, and Societal — the application in public health revealed the need for more differentiated perspectives. Public health experts broadly welcomed the addition of Intra- and Interorganizational levels, emphasizing that PHA operates within complex ecosystems of dependencies, internally (e.g., across departments) and externally (e.g., with municipal IT service providers or regional authorities). At the same time, focus group participants discussed that these newly added levels differ in character from the original ones: they do not represent distinct structural levels within an organization but describe relationships between existing levels or cross-level dynamics. Moreover, DR frequently involves multiple levels simultaneously. In this regard, the DR expert noted that, in practice, it is often insufficient to assign DR to a single level. Instead, coordinating and aligning responsibilities across levels matters — such as a PHA coordinating with a regional ministry or a department head acting on intra- and interorganizational concerns.
3. **To reflect this layered reality more accurately**, the DR framework could benefit from a dual conceptualization of levels: (1) Structural Levels (Personal, Corporate, Societal), which indicate where responsibility resides, and (2) Relational Configurations (e.g., Intra- and Intercorporate), which capture how responsibility is distributed, shared, or negotiated across entities or roles. In line with Trier et al. (2023), we retain the label corporate for consistency, while in the public health context, this level maps to organizational actors such as PHA. This dual conceptualization resonates with research in public administration that highlights inter-organizational gov-

ernance arrangements, distributed accountability, and multi-actor implementation chains (Kuhlmann & Bogumil, 2021). It also connects to organizational psychology, particularly the concept of Multi-Team-Systems (MTS; Mathieu et al., 2002). Such MTS contexts are defined by two or more teams interacting directly and depending on each other to achieve collective goals. Teams within an MTS must share at least one common distal goal and show interdependence with at least one other team within the MTS, while the individual teams can still pursue different proximal goals (Mathieu et al., 2002). In the PHS, such MTS can be found in different tasks and contexts. During the COVID-19 crisis, local PHA teams needed to coordinate with other PHA teams, teams from regional and federal ministries, hospital staff, and other relevant institutes to succeed with the pandemic management. But also, e.g., when implementing new software in local PHA MTS contexts are present. Project teams in PHA work together with teams from the communal IT department, software development companies, or other PHA also implementing the software. While all these teams have individual goals, they work together on one common goal, such as successfully implementing the new software. To succeed MTS require exceptional leadership and coordination (DeChurch & Marks, 2006) and must be seen as a separate level from single teams or whole organizations (Shuffler et al., 2015), illustrating why Intra- and Intercorporate dynamics merit distinct consideration as relational configurations alongside structural levels especially as the above mentioned specific leadership and coordination efforts are needed to achieve a common goal, or as participants from the workshop mentioned to coordinate responsibilities that are inherent to the structural levels. Future research may investigate how these relational configurations manifest and evolve in other public sectors (e.g., education, municipal administration), where federated governance and multi-actor dependencies pose similar challenges.

4. **Introducing the new DR Principle Security:** The coding process revealed Security as a new and distinct principle. It reflects the growing importance of cyber resilience and infrastructure protection (Aghazadeh Ardebili et al., 2024; Chowdhury & Gkioulos, 2021). While Data Privacy is included in the original DR framework, it does not fully capture the technical and operational dimensions required to protect IT systems that handle sensitive health data. The literature highlights the interconnectedness, as Security cannot be fully achieved without first addressing data privacy concerns (Milton, 2014). Experts in the public health context emphasized the need for secure health information systems and preparedness for cyberattacks, particularly where municipalities depend on shared IT service providers (Kandasamy et al., 2022; Puri & Gochhait, 2023). Beyond public health, research in other sectors demonstrates that Security is increasingly recognized as a distinct concern. For example, Tabansky and Lichtermann (2025) show that cyber resilience requires coordination at the sector-level, encompassing interdependencies across organizations in health, financial services, electricity, and digital infrastructure. Similarly, Araujo et al. (2024) emphasize in a cross-sector review that cyber resilience depends on integrated technical, organizational, and adaptive measures across industries ranging from aviation to supply chains. Even within the DR literature, the importance of security has already been mentioned, highlighting data security, besides data privacy, as a relevant aspect of DR that needs to be addressed (Carl et al., 2022). By embedding Security as a principle in its own right, the refined DR framework reflects empirical findings from (public) health (e.g. Chen & Esmaeilzadeh, 2024; Kandasamy et al., 2022; Puri & Gochhait, 2023) and aligns with broader debates in IS and governance (e.g., Bertino, 2016; Carl et al., 2022), emphasizing digital trust, resilience, and continuity across multiple sectors. Further research could examine how Security interacts with emerging technologies such as AI or blockchain and how sector-wide coordination mechanisms can be operationalized to strengthen digital resilience in public health and other critical infrastructures.

In summary, we refined and updated the structure of levels and principles of the DR framework, as shown in Fig. 4. The framework now includes an additional principle, Security, expanding the original set of eight. In addition, we differentiate between structural levels (Personal, Corporate, Societal) and relational configurations (Intra- and Intercorporate) to better capture organizational complexity and cross-level dynamics. This enhanced framework ensures that principles and levels are interlinked and adaptable to the specific needs of diverse sectors, particularly public health. Adapting the DR framework in this way becomes a more versatile and balanced tool, promoting a comprehensive and responsible approach to digitalization across organizational and societal contexts while accounting for multiple layers of execution and coordination.

Lessons learned from applying DR to PHAMM

To render the contribution of this paper more explicit, we derived a set of lessons learned from applying the DR framework to PHAMM. These lessons synthesize the main

conceptual takeaways from our analysis and highlight both design gaps in PHAMM and conceptual refinements of the DR framework. They also demonstrate how insights from contextualized research in public health can inform the adaptation of DR in other domains. Table 9 summarizes the lessons learned, their empirical origin, implications for the DR framework, and their relevance beyond public health.

As summarized in Table 9, several lessons extend beyond the immediate PHAMM context. The limited representation of some DR principles illustrates different types of gaps. For example, the underrepresentation of **Fairness** points to a design gap in maturity models, as fairness-related concerns such as equal access and non-discrimination are highly relevant in practice but not systematically included in existing frameworks (e.g., Juvalta et al., 2023; Raza et al., 2024). In contrast, **Norms & Values** represent a conceptual challenge of the DR framework itself. Intended as an open category to capture aspects not covered by other principles, they proved difficult to operationalize in our analysis, which explains the low intercoder agreement and marginal attribution to PHAMM criteria. Addressing these two types of gaps requires different strategies: embedding well-defined principles like **Fairness** more explicitly into maturity models, while refining open categories such as **Norms & Values** through closer linkage to sector-specific guiding values (Lewerenz et al., 2025). To strengthen the operationalization of such values, future iterations of PHAMM or similar frameworks should expand participatory processes to include groups that explicitly represent fairness and social values (e.g., patient organizations, civil society actors, diversity and inclusion advocates). Such inclusion would help ensure that normative concerns are systematically translated into concrete criteria and measures, paving further steps towards making DR measurable (Trittin-Ulbrich et al., 2025). Furthermore, **Security** emerged as a distinct and well-recognized principle, underlining the necessity to explicitly account for resilience and trust in public sector digitalization (Chowdhury & Gkioulos, 2021; Puri & Gochhait, 2023). These examples illustrate how contextualized analysis not only reveals design limitations of PHAMM but also informs the conceptual refinement of the DR framework.

Limitations and future research

In addition to the contributions of this study, several limitations should be acknowledged, which in turn offer opportunities for future research that extend beyond the avenues related to refining the DR framework discussed above.

First, the contextualization provided through our study should be interpreted with caution. This means that the frequency codes assigned to levels and principles should not be interpreted as a direct indicator of their relevance and importance for the public health sector. Accordingly, no interference should be taken from the number of codes in each category (DR level and principle) and their real-world criticality for DR transformation within PHS. For example, the principles Functionality and Accountability dominate the PHAMM's operational focus. Their dominance may partly stem from the purpose of the PHAMM itself, which is to enable a sustainable and measurable digitalization process within PHA towards a joint goal of digital maturity. Hence, functionality and accountability are inherently important to the model. Moreover, the frequency of DR principles within the PHAMM does not necessarily indicate whether they are adequately represented. While some principles might be necessary to describe in several criteria to enable a stepwise implementation of the principle, other principles might be fully represented by one, possibly broader criterion. This underscores that quantitative representation alone cannot fully capture the principles' impact, thereby necessitating a cautious interpretation of the findings and preventing an overemphasis on frequency within the interpretative process.

Second, while on the Corporate level, Accountability and Functionality are dominant, the DR principle Participation is widely represented on the Personal level. Yet whether this unequal distribution represents the optimum is unclear. The PHAMM was developed according to the current state of the art and knowledge about digitalization within the PHS, not evaluating and reflecting upon a possible optimization of the distribution of certain criteria and principles. Whether this unequal distribution of DR principles across levels is desirable or a more balanced distribution ought to be sought cannot be determined yet and needs to be addressed in future research. This uncertainty mirrors current broader debates in DR research on whether principles should be weighted equally or prioritized according to sectoral needs (Lewerenz et al., 2025; van der Merwe & Al Achkar, 2022), highlighting the importance of addressing this limitation in future research.

Third, as digitalization and research about its impact and implementation advances, the PHAMM criteria may no longer remain exhaustive. Thus, the contextualization of DR principles and levels will likely require ongoing refinement. This need for continuous adjustment is emphasized both in the DR implementation guidelines by Herden et al. (2021) and in the broader evolution of digital technologies, which constantly introduce new challenges that need to be addressed (Recker et al., 2025). Finally, this analysis is rooted in the context-specific field of PHA, and its applicability to other sectors remains uncertain without further research. The uneven distribution of principles across levels observed in this study (see Table 5 and Fig. 3) might differ in other contexts where priorities and operational structures vary. This aligns with prior research highlighting the context-dependent nature of DR frameworks (Merbecks, 2024). To address this limitation, future studies could pursue broader empirical validation of the refined DR framework in

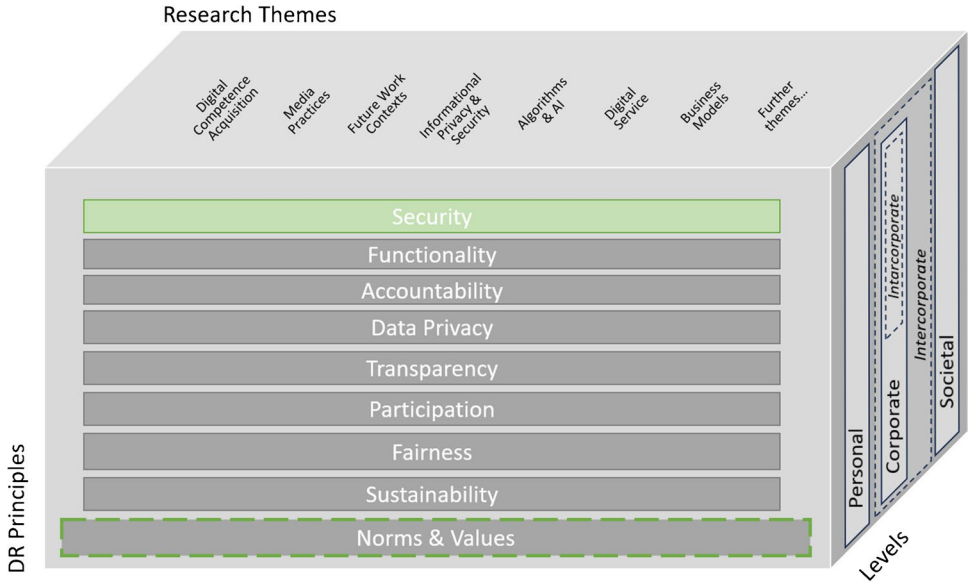

Fig. 4 Evolving the DR framework based on Trier et al. (2023); levels distinguish structural levels (solid lines), which indicate where responsibility lies, and relational configuration (dashed lines), which describes how responsibility is distributed within and across levels

diverse public health settings, ideally through longitudinal studies that investigate how embedding DR principles affects outcomes such as equity, efficiency, and trust. Moreover, the transferability of the refined DR framework to other public sectors (e.g., education or local authority) could be systematically examined, particularly regarding the role of Intra- and Interorganizational configurations in federated systems where interdependencies are a critical governance challenge (Kuhlmann & Bogumil, 2021). At the local authority level, the enhanced DR framework could be systematically assessed in the context of administrative services, including citizen portals and e-government applications. This assessment and evaluation would also enable an investigation of the detailed operationalization of principles such as Security, Transparency, and Accountability. Within the broader validation of the refined DR framework, a focus on emerging technologies such as AI or blockchain might be valuable. These emerging technologies raise new questions for DR, particularly concerning transparency (e.g., explainable AI), accountability (e.g., Who is responsible for wrongly provided content through GenAI on a governmental website? Wo is responsible for the decisions supported by AI?), and algorithmic bias (e.g., How can "unbiased" data be used to train algorithms? How can we detect biases in AI and address them?) and could be integrated into future studies of DR in public health and beyond (Chowdhury & Gkioulos, 2021; Tabansky & Lichterman, 2025).

Conclusion

This study bridges the DR framework with the PHAMM, offering a nuanced perspective on responsible digital transformations in public health. Addressing the call for a comprehensive non-corporate perspective and contextualization of DR we investigate to what extent does the PHAMM-guided PHA digitalization reflect the DR principles and levels and what refinements to the DR framework emerge from its application in the PHS. We uncovered gaps by applying and contextualizing DR principles and levels within PHAMM and validating them through focus group expert input. We refined the DR structure, adding Security as a principle and differentiating structural levels (Personal, Corporate, Societal) from relational configurations (Intra- and Intercorporate). The Intracorporate relation emphasizes structured communication across departments, while Intercorporate relations highlight collaboration and data sharing with external partners.

From a practical perspective, the refined DR framework enables PHA to develop, implement, and evaluate digitalization strategies that ensure ethical integrity, technical resilience, and social inclusiveness. It guides policymakers and public health leaders to address ethical blind spots, adapt funding mechanisms, and update maturity models for more responsible digital transformation. In doing so, the paper resonates with DR implementation guidance that emphasizes systematic steps toward operationalization (Herden et al., 2021).

From a research perspective, the study demonstrates how the DR framework can be adapted to a specific complex and multiple actor domain — public health. The mapping of DR principles and levels onto a domain-specific maturity model offers a method for testing and tailoring DR frameworks in applied settings, responding to the challenge that guiding values in digital health are often plural and difficult to codify consistently (Lewerenz et al., 2025). The study also provides subcategories for each principle and level, allowing for a more granular, operationalized framework, with many elements generalizable to other regulated public sectors.

Table 9 Lessons learned from applying the DR framework to PHAMM and their broader implications

Lessons Learned	Origin in PHAMM/DR analysis	Implication for DR Framework	Relevance beyond public health
Fairness is underrepresented	• Few PHAMM criteria coded • Strong emphasis in focus group on equal access and non-discrimination	• Indicates a design gap in maturity model • Fairness must be made explicit	• Highlights the need to integrate fairness into digitalization strategies across public services (e.g., education, social care)
Norms & Values act as residual category	• Low intercoder agreement • Expert clarification on conceptual vagueness	• Highlights a conceptual gap in the DR-framework • Requires sharper definitions or linkage to sector-specific values	• Generalizable to all domains where normative principles remain diffuse
Security emerges as a distinct principle	• Strong coding agreement • High relevance in PHAMM IT-Security dimension • Strong emphasis on relevance in focus group	• Should be added as a new DR principle to ensure reliance and trust	• Critical across sectors handling sensitive data (e.g., justice, finance)
Relational levels are needed	• PHAMM highlights intra- and interorganizational dependencies	• DR framework should differentiate between structural and relational levels	• Transferable to multi-actor ecosystems (e.g., crisis management, smart cities)
Functionality & Accountability dominate	• Majority of PHAMM criteria coded • Clear operational focus	• Confirms robustness of these principles but shows uneven representation across principles in general	• Suggests that maturity models in other sectors may also overemphasize operational aspects
DR contextualization leverages further insights	• Extension of DR framework through contextualization • Defined subcategories for principles and levels • Refined understanding, clarity and importance of principles, levels and relations between them	• Highlights need to contextualize DR framework to more application fields • Possibility to gain further insights into a comprehensive DR framework	• Possibility to find more levels and principles in other contexts or a different prioritization of these

Furthermore, the study proposes refining the DR framework by introducing Security as a new principle and relational configurations as an extension to capture distributed responsibilities and interdependencies. This refinement aligns with broader debates on strengthening resilience and cybersecurity in socio-technical systems (e.g., Chowdhury & Gkioulos, 2021; Puri & Gochhait, 2023) and on multi-actor governance (Kuhlmann & Bogumil, 2021). Overall, the refined DR framework offers actionable pathways for integrating responsibility into broader public sector initiatives, aligning digital innovation with societal values and ethical standards.

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