Generative mechanisms of information use for project monitoring in humanitarian health management information systems

Master thesis

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September 21, 2020

A thesis submitted in fulfillment of the requirements
for the Master's degree in Information Sciences
at Vrije Universiteit Amsterdam

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Abstract. Humanitarian medical organizations operating in protracted crises face extremely dynamic environments. They rely on information on the ground to prove their effectiveness and accountability, an expectation where its fulfilment is driven by implementations of ICT. In the transition of immediate relief towards longer-term development, the digitalization efforts within health information systems aim to yield actionable insights in and across projects in order to achieve sustainable impacts. Monitoring relies on routinely collected and assessed data; however, previous research has shown that a multitude of factors influence actual information use for evidence-based decision-making in health management information systems. This case study empirically examines a globally operating humanitarian organization (Médecins Sans Frontières) by drawing on the philosophical framework of critical realism. It aims to highlight the contextual conditions and structures that enact the contingent mechanisms at work in project monitoring within humanitarian health management information systems. By applying an affordance-based causal analysis, three generative mechanisms are identified. First, an analytics service provides templated analysis modalities resulting in user-producer-provider relationships. Second, the rationalization and synchronization of content gives rise to the standardization strategy of flexible generification. Third, the study uncovers the potential for increased internal social discourse and advocacy through collaborative and mobile data analysis. This thesis in humanitarian health information systems demonstrates that mechanism-based explanations can be useful for theory-building in information systems research.

Keywords: ICT4D · Humanitarian organizations · Health management information systems · Case study · Critical realism · Affordances

1 Introduction

Humanitarian emergencies occurring in different parts of the world have been causing the largest number of refugees, internally displaced and entrapped persons in a generation [33]. Protracted situations, such as those resulting from armed conflicts, epidemics or natural disasters, are chaotic. Humanitarian decision-makers work under stressful, high-pressure conditions that can introduce or enforce biases [10]. Valid and timely information can counter these biases and lead to improved decision-making. The goal of public health information in emergencies is i) to answer questions about the affected population's health status, location and characteristics; on the immediate and long-term risks; and on appropriate resource allocation; and ii) to foster local participation to ensure continuity after the crisis [34]. Public health information is also important for advocacy and documentation purposes [8] and required to improve the efficiency, effectiveness and sustainability of humanitarian interventions [33].

Short-term emergency responses addressing immediate needs can evolve into long-term interventions [33, 36] that require both multi-actor coordination as well as the routine collection and assessment of information, which in turn needs to be disseminated to on-site and remote decision-makers that approve interventions. Monitoring, or the frequent and systematic gathering of information to track progress against objectives, encompasses project-based decision-making, tracks performance and quality, improves accountability to stakeholders and is linked to organizational learning between projects [41]. In a 2018 review of a sector-wide network of the humanitarian system, one conclusion was that despite ongoing efforts in the areas of information collection for impact and outcome monitoring, as well as more adaptable and context-specific programs, substantial improvements have not yet occurred [1]. Reasons include the complex settings in which health technologies are deployed and disseminated [22], such as intermittent or expensive connectivity, unsafe environments and handling of highly sensitive data.

Still, humanitarian organizations are expected to demonstrate their effectiveness and accountability to both donors and recipients of aid. The organization's information system (IS) is critical in fulfilling this demand [20, 31]. Previous research identifies various factors, such as data quality and availability, individual capabilities and governance, in their contribution to how information is used for evidence-based decision-making in efforts to strengthen health systems, but less is known about humanitarian medical organizations that use information for project monitoring and surveillance. Research activities are ongoing, for example in *RECAP work stream 4* at the London School of Hygiene and Tropical Medicine where the objective is to study the "current use of data and evidence in operational decision-making and the potential for innovative decision-making approaches and technologies in humanitarian settings" [21]. This study aims to contribute to this research area by elaborating on which structures and conditions exist for information use to take place within the context of project monitoring with humanitarian health management information systems (HHMIS). The study is guided by the following research question:

Which generative mechanisms contingently lead to effective use of information for project monitoring in international humanitarian medical organizations?

It draws on literature from ICT4D (information and communication technology for development) and health information systems (HIS) disciplines as well as on the philosophy of critical realism to develop the contingent conditions and structures of mechanisms related to information use in a case study of the HHMIS of a globally active non-governmental organization. The study's data was collected through key informant interviews, document reviews and existing empirical literature. It applies a data analysis methodology based on the underpinnings of critical realism.

This paper proceeds by providing a brief overview of the issues related to information use in the context of humanitarian aid and development in Section 2. The theoretical and conceptual foundation is presented in Section 3, followed by the research methodology in Section 4 and case description in Section 5. The case findings—the affordances and mechanisms identified—are presented in Section 6, followed by the discussion and practical implications in Section 7 and conclusions in Section 8.

2 Background and related work

In 2012, Walsham argued that the unifying vision for the information systems (IS) discipline should shift from asking, "how do we use ICTs more effectively to help organizations?," to widening the scope and critically analyze who eventually benefits and who is left out, thereby asking: "are we making a better world with ICTs?" [39]. ICT4D plays an important role in this debate. Heeks suggests an ongoing paradigm shift is taking place in international development towards a 'digital nervous system' permeating most development organizations: "the iconic technology is now the digital platform, the key goals are the SDGs [the United Nations' Sustainable Development Goals], and the key issue is now impact alone" [16]. The new paradigm ('digital-for-development') will have, or already has had, a substantial influence in the coming decade with implications for social justice and inequality as well as development efficiency and effectiveness [16].

In humanitarian responses, a challenging expansion from approaches addressing immediate needs towards long-term solutions for preparedness and resilience has occurred in the last decade [33]. In this humanitarian-development nexus, donors demand value for their investments. Beyond funding, partnerships with the private sector can enhance efficiency [33]. However, within an increasingly strategic, programmatic and corporate sector, the techno-optimism within humanitarian information systems should be examined academically—especially when organizations adopt and experiment with new approaches and technologies such as crowd-sourcing, big data, or predictive analytics—in order to see whether it helps local empowerment or rather reinforces neoliberal worldviews and asymmetric power relations [31] or promotes paternalistic approaches of technology adoption [22]. The need for greater integration of local knowledge

has been widely recognized [1, 5, 31, 33, 40], an issue addressed by replacing linear long-term development "interventions"—considered to be a discourse and strategy of the Global North—with iterative, adaptive and collaborative approaches with the Global South [5]. However, changing the existing (and as part of effective emergency response often required) structure of upward reporting systems and related hierarchies towards more horizontal information sharing requires a lot of institutional resources and willpower. Nevertheless, the change promises to transform the power relations between donor and the disadvantaged and provides an opportunity for organizing better responses and improved healthcare [31, 40].

ICTs play an essential role in improving the effectiveness of action in the health domain. Yet, they cannot be implemented in isolation to solve complex issues of empowerment or break down the hierarchical nature of organizations. Rather, they need to be embedded in a broader view of technological, social and institutional innovations [40]. The related socio-technical process of 'digitalization' is leading to the digitization of content and concomitant reconfiguration of roles, relationships, practices and organizational structures [14]. In the context of developing countries, it is further characterized by diversity, complexity and significance (of IS research and digitalization as a key driver of development) [14]. A wide range of types of digital technology facilitating communication, coordination, collection and analysis of data is being piloted or has already been adopted by humanitarian actors and affected populations. They pertain to geographic information, spatial decision support, electronic health records or hand-held data entry [22]. This study focuses on (another common) type of digital technology employed by humanitarian actors: surveillance systems which are concerned with "the collection, analysis and interpretation of health data to guide interventions in real time" [22]. This is achieved through the use of a health management information system (HMIS) that "stores aggregate health care data, such as disease incidence rates as well as quality indicators [...] which are routinely collected measures defined by public health organizations" [11]. The performance of routine health information system has been defined by Aqil, Lippeveld and Hozumi as improved data quality and continuous use of information, both being outputs of various interconnected processes with organizational, technical and behavioral factors [2]. Drawing on these findings, Nutley and Reynolds have developed an intervention framework to guide improvements in data demand and data use for Ministries of Health or non-governmental organizations. They defined data use as as "the analysis, synthesis, interpretation and review of data for decision-making regardless of the source of data." A literature review by Kumar, Gotz, Nutley and Smith found that system design factors influencing data quality or data use for decision-making, such as user involvement, work flow, human-computer interactions or user experience, are mostly absent in HIS literature [19]. Others have identified the individual data literacy as well as the 'information culture' of organizations to be determinant or supporting factors for effective decision-making [2, 19, 29].

So far, research on conditions for effective information use in the context of humanitarian HMIS is sparse. Vila-Pozo and Sahay apply institutional theory to identify three factors to the use of data in a medical humanitarian organization: *operationability* (use data to follow-up trends and identify alerts for constant response and adaptation of activities); *accountability* (use data to be accountable for day-to-day activities and operational decisions); and *contextuability* (use data to know and analyze the context when you are new to the situation) [37]. In an earlier paper, the same authors identified institutional contradictions that showed how software design affected day-to-day work: *stability* (the issue of new formal software design methodologies vs. institutionalized work routines of staff); *dependencies* (on stable Internet vs. the opposite reality in the field); and *homogeneity* (fluctuating numbers of displaced population figures vs. ability to appropriately map these dynamics in the HMIS) [36].

3 Theoretical foundation

The multitude of identified factors of information use in health information systems precludes the isolation of one phenomenon in a controlled study, as a force outside of the constrained environment can be a non-negligible factor in the influence on the phenomenon in question. In an open system, we must assume a dynamic and variable reality that is influenced by technological, social, organizational and environmental factors, and it is necessary to methodologically ask *why* a certain phenomenon—information use—developed in order to improve it for increased effectiveness.

Critical realism (CR) has emerged as a new (by philosophical standards) and legitimate alternative to positivist and interpretive approaches to IS research in the past two decades [7, 14, 17, 23, 27, 35, 42, 43]. Initially, the philosophy of CR was formulated by the British philosopher Roy Bhaskar in the 1970s [4] and extended by Bhaskar himself as well as Sayer [32] and others in the 1990s. As a philosophy of science it includes specifications about its ontology (assumptions about the existence of the world and society) and its epistemology (the study of how knowledge is possible).

3.1 Principles of critical realism

Even though there is no unitary framework, three core assumptions underlie the philosophy. *Ontological realism* argues that reality is independent of our perception and knowledge. *Epistemic relativism* states that our knowledge of this world is limited, fallible and contextual. *Judgemental rationality* refers to the commitment to the rational evaluation of the diverse and sometimes conflicting theories about the world. This rationality is i) enabled by independent reality, and ii) necessitated by the relativity of our knowledge: if reality is intransitive and independent, and we only have fallible theories in our own transitive reality, there must be a rational judgement on the plurality of assertions of this world for science to be possible.

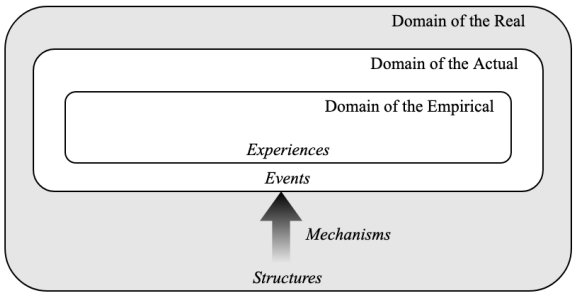

Fig. 1. Stratification of reality in critical realism

Adhering to these principles, a stratification of reality in three nested domains is specified (visualized in Figure 1). The *real* consists of physical and social *structures* (such as organizations, norms, cultures) and *mechanisms*, which may (or may not) generate *events* in the second, *actual* domain, which states what must have occurred even though it might not be (possible to be) empirically perceived. In the third domain, the *empirical*, these events may be observed or *experienced*. In that sense, structures have the potential to enable or constrain events through generative mechanisms which are "nothing other than the ways of acting of things" [4] (the definition of a CR-based mechanism has been repeatedly refined, see [42]). The intransitive dimension of a reality consisting of structures, mechanisms and processes exists independently from our knowledge in the transitive dimension. CR states that knowledge of the world is emergent, political and imperfect; Bhaskar termed the mix of these two the 'epistemic fallacy,' the essential mistake of reducing the ontological domain of existence to the epistemological domain of knowledge, so that statements about our existence are translated in statements about our knowledge of being [23]. What follows is that critical realist researchers do not have immediate access to the intransitive dimension but reason about reality (the structure and mechanisms) through abstract causal analysis of the concrete events generated by mechanisms in order to create knowledge within the transitive dimension. "Concrete research studies actual events and objects as 'unities of diverse determinations,' each of which has been isolated and examined through abstract research" [32]. Empirical or actual events can be created or cancelled by a single or multiple mechanisms, and structures can generate one or multiple mechanisms. These descriptions of dependencies and emergence are visualized in Figure 2.

The main two reasoning methods for causal analysis are retroduction (identifying new mechanisms based on the metaphorical application of prior knowledge) and retrodiction (application of known mechanisms to explain different phenomena) [43]. Mechanisms do not imply a linear causality, producing the same outcome every time it is generated. Instead, mechanisms are contextual and dependent on other mechanisms.

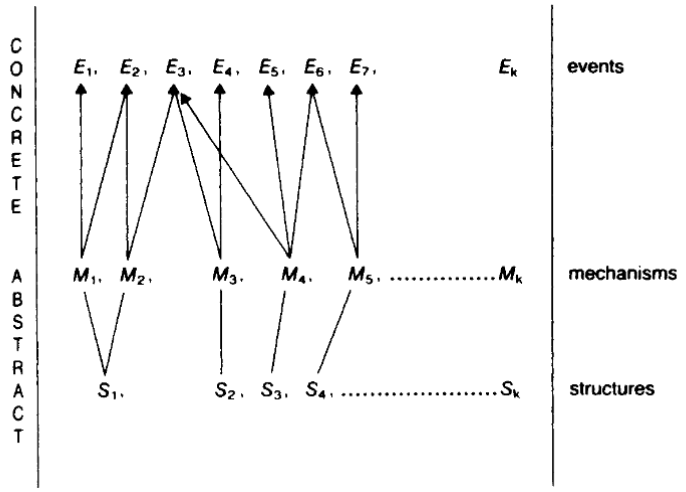

Fig. 2. Structures, mechanisms, events (Fig. 8 in [32])

The lack of specific inclusion of technological artifacts in CR-based IS research required a more ICT-specific integration. Using Gibson's affordance theory from evolutionary psychology, Volkoff and Strong specify how affordances are a subset or specific form of generative mechanisms [38]. Affordances in the IS context are defined as "the potential for behaviours associated with achieving an immediate concrete outcome and arising from the relation between an object (e.g., an IT artefact) and a goal-oriented actor or actors" [7, 38]. Bygstad, Munkvold and Volkoff state that explicit methodological approaches that include technology artifacts were lacking beyond i) the principles of CR, ii) related logic model of retroduction and retrodiction, and iii) principles for CR studies in IS [7]. Their pragmatic approach on how to do critical realist data analysis in IS research provides two potential benefits: i) link specific IS and ICT directly to actors and, in doing so, describe their inherent capabilities and limitations; and ii) more tangible methodological guidance [7]. The core assumptions and practical extensions are guiding the methodology of this study. Further rationale for the application of the affordance-based framework is given in Section 4.

3.2 Critical realism in ICT4D research

As an IS-related discipline, ICT4D is suitable for CR-based research approaches. CR-based ICT4D research makes use of an "iterative, pluralist and reflexive methodology with emancipatory values" [17]. It forces an involvement with the ICT4D context based on what exists (local expertise, needs and adaptive capabilities) and how it evolved over time, rather than perceiving development as what is lacking [27]. Identified generative mechanisms can further be tested and used in action research [7] as a basis for strengthening the exchange between

theory and practice, a direction that is in need of further examination in critical ICT4D research [5].

4 Methodology

To answer the research question, the research approach consists of an in-depth case study of the digitalization efforts of three sub-organizations (Operational Centres, or OCs) of an international humanitarian medical organization towards a web-based online platform for monitoring and surveillance. The unit of analysis are practitioners of digital health within the organization, namely managers, advisors, users and researchers of the platform. A case study was chosen as it is "an empirical inquiry that investigates a contemporary phenomenon within its real life context when the boundaries are not clearly evident and in which multiple sources of evidence are used" [44]. Critical realism is well suited to conduct case studies [35, 43] and thus a fitting method to answer the research question.

4.1 Data collection

Data collection was conducted iteratively and involved five semi-structured interviews with six interviewees as well as document reviews. The audio- and video-interviews were conducted remotely between June and August 2020. The interview protocols were iteratively adapted for each new interview. The questions, however, always revolved around the following themes:

- The use of information or provision of the enabling platform features
- Challenges and benefits compared to earlier monitoring or digitalization approaches
- Opinions about statements from earlier interviewees or relevant literature
- Impact of structural and environmental issues in international development (e.g. Logframe, Internet connectivity) on their daily work

Before each interview, informed consent was gathered in order to ensure permission for the recording of the interview. During or after the interview further contact details were provided by interviewees or asked for by the interviewer. The participants were identified on a purposive sampling strategy based on their involvement with the organization's HIS. Table 1 lists the details of the interviews. The OCs have been anonymized to limit identifiability.

In order to get an understanding of the structure and events of the organization but also to pose specific questions in the interview protocol, annual reports and research literature were included if they specifically related to the organization's IS.

Table 1. Interviewees and interview duration

Name	Position	OC	Duration
Interviewee 1 (INT1)	Program manager	1	50min
Interviewee 2 (INT2)	eHealth epidemiologist	1	
Interviewee 3 (INT3)	Humanitarian HIS researcher	2	70min
Interviewee 4 (INT4)	Medical officer	1	45min
Interviewee 5 (INT5)	eHealth epidemiologist	2	50min
Interviewee 6 (INT6)	HIS medical content advisor	3	55min

4.2 Data extraction

Bygstad, Munkvold and Volkoff's framework for critical realist data analysis was used [7] as it provides a methodological tool to identify and analyze mechanisms. After transcription of the interviews and review of documents, the data was open-coded with the qualitative data analysis software ATLAS.ti in multiple iterations. In the second cycle, the codes were grouped into the following framework-specific categories:

- Human & technical entities, such as IT artifacts, sub-organizations, teams and stakeholders
- Immediate concrete outcomes
- Actor's goals for the platform
- Enabling, stimulating or releasing conditions

Starting from the most-occurring codes in each group, these categories were used to iteratively sketch affordances through the mapping of conditions, structures and low- and high-level outcomes. The process of retroduction from case data is intended to be highly creative [35, 42, 43]. Additionally, the network of conditions, affordances and outcomes was mapped to identify shared conditions and outcomes of affordances and enhanced with relevant and applicable IS theory and previously identified mechanisms (retrodiction). The affordance emerges from the relation of technology and actor leading to a concrete outcome under enabling, stimulating and/or releasing conditions, which subsequently can alter the structure where it emerged [7]. The affordance model is illustrated in Figure 3.

Finally, mechanisms were invented by analyzing dependencies between affordances, grouping affordances, mapping to existing mechanisms and abstracting into higher-level mechanisms [7] and assessed by its explanatory power against the empirical evidence [7, 32].

4.3 Rationale

This methodology was chosen due to the practicality of the framework. Its strength lies in pragmatically reasoning about causality in IS by mediating the

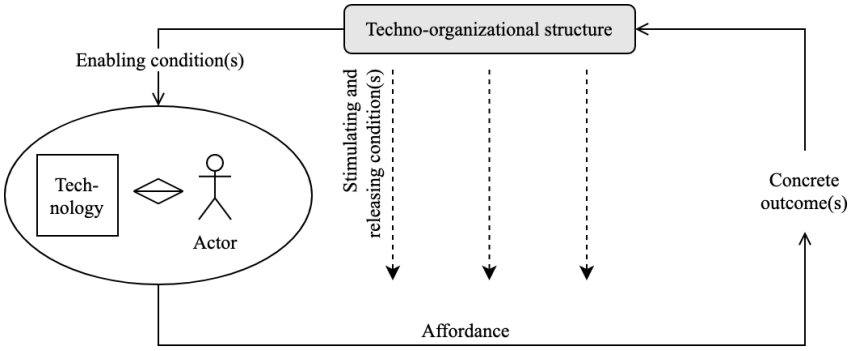

Fig. 3. Affordance viewpoint (adapted from Fig. 2 in [7])

abstract CR concepts with more tangible affordances, as argued in Section 3. Additionally, the researcher's practical professional experience in working as a software engineer in the domain of global health and international non-governmental organizations helped him to understand the wider context and tacit knowledge. At the same time, it increases the risk of bias which the study design accounts for and seeks to mitigate: the interview data and analysis was checked and compared against documents, reports and other empirical literature.

5 Case description

5.1 Médecins Sans Frontières

This paper examines the case of the project monitoring digitalization efforts of three Operational Centers (OC) of Médecins Sans Frontières (MSF), a global humanitarian medical non-governmental organization (NGO). MSF provides emergency medical assistance to people affected by natural or man-made disasters, irrespective of race, religion, creed or political convictions [25]. MSF concentrates primarily on healthcare—as one of the last few international humanitarian agencies it does not rely on a "cumbersome coordination system that prioritizes process over outcome," which increases their response effectiveness [33]. The overall organization has an associative structure of five OCs where operational decisions are made relatively independently. MSF operates in various countries where projects are coordinated through in-country coordination offices. The OCs report to the international council and international office, and various cross-OC teams exist on specific medical or organizational topics.

The following OCs were included in this study: Amsterdam (OCA), Barcelona-Athens (OCBA) and Brussels (OCB). Due to the independence of OCs, the types and related onsets of digitalization processes vary, but the common theme for all has been a gradual shift from using spreadsheet software on a per-project basis towards a web-based integrated health information system for the medical-

operational monitoring (or surveillance) of projects. The distinct and shared processes and events are displayed as a timeline in Table 2.

Table 2. Timeline of key events recorded

ID Event	Operational Center	2015	2016	2017	2018	2019	2020
E1 Excel as main tool for data collection	OCA, OCB, OCBA	x	x				
E2 Creation of eHealth units, formulated goals of integrated HIS for monitoring	OCA, OCB	x	x				
E3 Piloting and scale-up of DHIS2 and legacy data migration	OCA, OCB, OCBA		x	x	x		
E4 Partial adoption of data and metadata synchronization	OCBA, OCA, OCB			x	x	x	
E5 Partial adoption of integrated reporting app	OCA					x	x
E6 Increase in directly-online projects	OCBA						x
E7 Processes of downsizing and rationalization of metadata	OCBA, OCA						x
E8 Integration processes of non-standard projects	OCBA						x

5.2 DHIS2

All OCs of MSF have transitioned towards using District Health Information System 2 (DHIS2) for their HMIS for project monitoring and surveillance. DHIS2 is an open source, web-based HMIS platform in use by 67 low and middle-income countries (LMIC) as well as many non-profit, non-governmental and multi-national organizations. Approximately 2.3 billion people are covered by DHIS2 [26]. Core development and governance is carried out by the global Health Information Systems Program (HISP), a "network of North-South-South collaboration." The University of Oslo is a key actor in the coordination of the program [26].

DHIS2 is part of a promising foundation for HMIS in LMIC to achieve the Sustainable Development Goals, and DHIS2 "should become the primary source of quality data for resource allocation and impact measurement" in the public health domain [12]. Still, concerns and issues remain: data is primarily collected in health facilities by overworked healthcare workers and later manually tallied and entered, which introduces delays and errors; these facility-level workers are not aware of the purpose of the collected data within the information life cycle; facility-level capacity building is often inadequate or non-existent; wide-ranging data quality issues are prevalent; and Internet connectivity challenges persist [12].

However, the flexibility and adaptability of the platform and related metadata model enables NGOs, such as MSF, to implement the software as their own HMIS and, if necessary, to extend functionality through platform apps compatible with the open software architecture [26]. Thus, an organization can participate to some extent in the development of a horizontal approach or "bottom-up empowerment" [40]. Since the Ministries of Health in countries where MSF operates often also use DHIS2 as their national HMIS, synergies are possible, for example, in data sharing, data integration efforts or capacity building. However, as ministries often do not have the necessary skills and resources to completely

take ownership of a new system or a subsequent data integration, they rely on the expertise of intermediaries such as the NGO, continuing or exacerbating the dependency on external technical assistance to adapt the generic tool of DHIS2 to their own specific and changing needs [26]. To alleviate this, initiatives that build capacity are necessary, for example through data-use workshops. These 'collaborative peer reviews of practice' have proven to be effective to improve the link between data quality and information use in national HMIS [6].

6 Analysis: mechanisms

Three mechanisms were identified for the organization's project monitoring through the HHMIS: templated analytics service; standardization; and collaborativity & mobility.

All affordances have structures of a human, social and technical nature (the techno-organizational structure [7]) that were laid out in Section 1, 2 and 5 and make for the context in which the affordances emerge. The technology is the HHMIS platform (DHIS2).

6.1 The templated analytics service mechanism

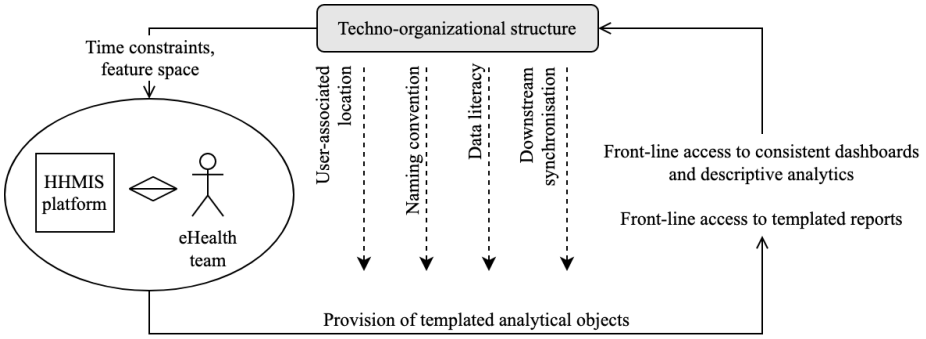

Fig. 4. Templated analytical object provision affordance

The first affordance that contributes to the mechanism is visualized in Figure 4 and describes the provision of templated dashboards and reporting tools. The enabling condition identified are the generally recognized time constraints on humanitarian front-line staff coupled with the feature space (available functionality) of the HHMIS. The eHealth team, usually based in headquarter offices with specialized digital health expertise, provisions the front-line teams with templated HHMIS dashboards containing user-adaptive items, as well as access to user-adaptive reporting tools. A dashboard is a collection of key performance

indicators for a given thematic area, containing dashboard items of analytical objects (data visualizations, such as charts or maps, and data tables, such as pivot tables) [9]. The conditions for the actualization of this affordance are that the items contained in these dashboards are configured based on the current user's associated or preferred location (the where-dimension or the "user-orgunit"), which enables an adaptive user interface. One participant (INT3) stated: "they need predefined objects, like a predefined dashboard, a predefined chart, then they would use it." The affordance is also stimulated via a relatively strict naming convention (a generally agreed scheme for naming metadata entities) to manage metadata in the HHMIS. The dashboard as a whole and the assembled dashboard items can only be provided effectively when their design quality is high, which depends on the data literacy of the designer [9]. These objects are then distributed as part of the configuration package by a downstream synchronization (see affordance in Section 6.2).

The concrete outcome is that front-line teams have access to consistent dashboards containing descriptive analytics for operational decision-making and related reporting tools. Standardized dashboard packages provide a level of consistency [9]. Descriptive analytics "describe or summarize datasets making them interpretable to researchers. They allow to learn from historical events or behaviors, and understand how these may influence future events or outcomes" [18]. Descriptive analytics require more human effort to reach a decision as compared to predictive analytics, which provide estimates on the probability of future outcomes [18]. The affordance described here provides the most common analytical approach but requires guidance. One participant (INT2) stated: "what we trial for most [projects] is to build the dashboard that is in line in how we should use the data ... because the dashboard will be like a guidance in how you should look into your data."

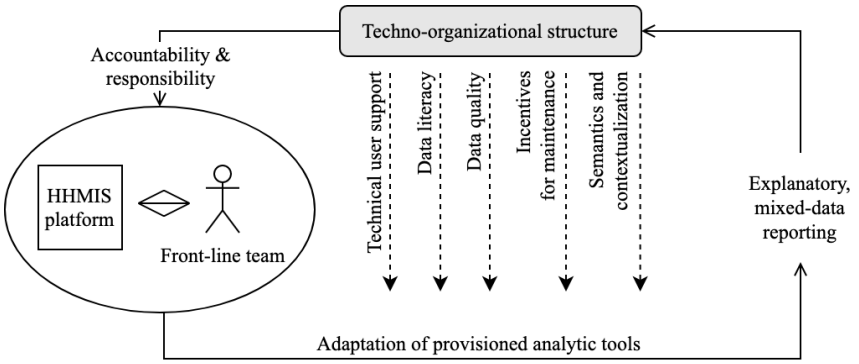

Fig. 5. Adaptation of provisioned analytic tools affordance

The second affordance, depicted in Figure 5, shows how the front-line team accesses these provisioned objects. The enabling condition is the shared under-

standing of the responsibility to access the platform in order to monitor the relevant indicators and the accountability of their work by backing up decisions with HHMIS-based evidence. The intrinsic value of data and data systems is generally recognized [28, 37]. A stimulating condition is the ability of the front-line team to easily reach out for user support in case of technical challenges. Other stimulating conditions identified are data literacy [9] and data quality of analytical objects. Another factor is an incentive for maintenance of the dashboard and its items, as their configurations need to be updated to be useful in changing contexts and requirements. This can be quite a challenge if *analyzing* data is already demanding—one interviewee (INT4) stated: "if you are the front-line doctor or medical person, you don't really have time to do all the analysis of the data, you are really concerned with treating the patient." This incentive is supported by intuitive user interfaces that work for less technical staff. User-designed dashboards commonly have context problems where i) no comprehensive or useful message can be drawn from them, ii) dashboard items are not linked, iii) descriptions are missing, or iv) items are not aligned with the purpose of the dashboard [9]. These conditions also hold true for a specific example of one OC: they developed a platform app that allowed for document-based, templated reporting of qualitative data (a narrative as found in the project situational report or 'sitrep') with quantitative data (target-based analytical objects exported from the HHMIS) based on the aforementioned naming conventions. Sitreps are commonly used to disseminate information to and from relief workers in the field. They are intended for a cosmopolitan audience of humanitarian actors and are painstakingly produced on the ground [13]. In the highly dynamic environment of humanitarian work, qualitative data is then used to give context, to justify and explain the quantitative data to a diverse set of recipients. One interviewee (INT5) stated: "the people [that are not here] just can see the indicators and numbers, but sometimes the numbers are meaningless if you don't put any context behind." However, here context means "the needs of the local population and the response of local governments and the humanitarian actors plus the gap of unmet needs" [13]. The outcome of this affordance is explanatory mixed-data reporting, for example through sitreps, which act as the basis for discussion and evidence-based justifications of "their" data with higher levels. Often, the individual-level records are never transmitted due to data protection regulations.

The major challenge of the interplay between these affordances' actualizations is the contradiction of one of the enabling conditions (time constraints of front-line staff) with a stimulating condition (incentives for the required maintenance of the dashboard and items). Through abstraction of these two affordances, this mechanism is based on the institutional accountability processes and capabilities emerging from the structure. They serve as the basis for the analytics service provision and result in specific roles with regards to data collection, use and service provision. Front-line staff—who access their project-specific data which they routinely manually aggregate, tally and enter, and who use both this activity and the dashboard for their day-to-day monitoring—are data *producers*

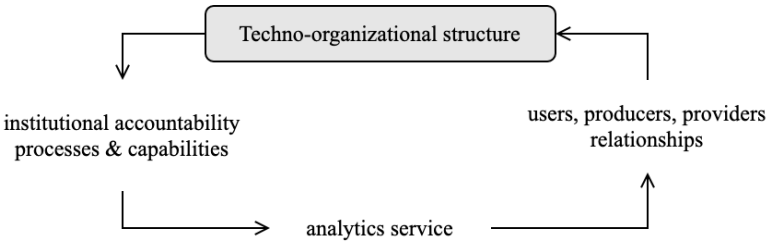

Fig. 6. Analytics service mechanism

and users and analytical service *users*. The "higher-level" staff—in coordination offices or headquarters who access aggregated data of multiple projects—are data *users*. The eHealth team acts as an intermediary, the *providers* of the analytical service but are neither data users nor producers.

6.2 The standardization mechanism

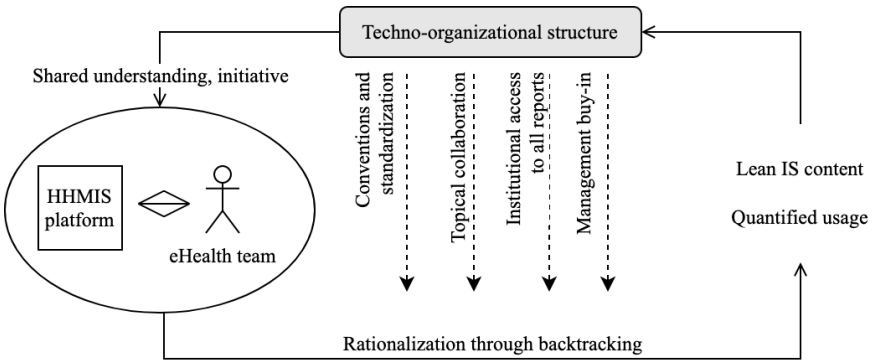

Fig. 7. Rationalization affordance

The mechanism is based on two affordances. The first affordance, visualized in Figure 7, relates to a rationalization via backtracking of metadata, resulting in quantified usage and leaner IS content. The enabling condition is an initiative based on a shared understanding that too many data points not used in reports were being collected. The affordance was stimulated by existing naming conventions in concert with management buy-in, which fuelled the ability of the eHealth team to institutionally access all relevant reports together with topic experts. This affordance led to a quantified usage of data collection, which

reported how much of the actual data collected is eventually used (in reports), leading to a leaner content within the HHMIS and reducing the burden of collecting data for front-line project teams. This is beneficial. If resources invested in the information-gathering capabilities of humanitarian actors outweigh the capacity to deal with the information, it indicates an inefficiency. In such a case, a simplification exercise can be a factor in becoming more efficient [31]. A discourse on whether analysis possibilities are already saturated with existing data might provide another promising tool to increase effectiveness. Finally, a means to highlight the history and origins of data (often termed data provenance or data lineage) can increase ownership, as one participant (INT6) stated: "When I was a doctor [at the organization] and collected so much data, that was also a part of the role including all the clinical management. What I did miss out on was: where is this data going and what's happening to my project, how am I contributing." Furthermore, data provenance can establish data origin, the chain of custody and reproducibility and automate data integrity checks [30].

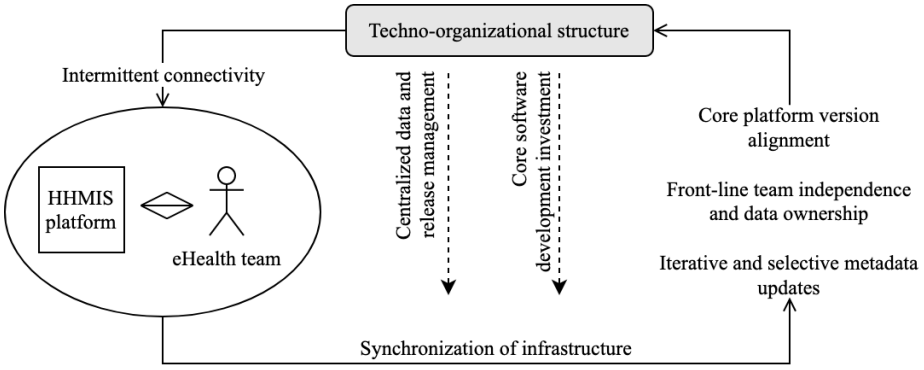

Fig. 8. Synchronization affordance

The second affordance is depicted in Figure 8. It relates to an existing feature within the HHMIS platform to address the problem of intermittent Internet connectivity. The platform has the ability to link partly offline servers in the countries of operation to a central online instance, for example managed at headquarters. The locally deployed servers i) update their HHMIS configuration from the central online instance, and ii) regularly upload collected data upstream conforming to that configuration to the central instance as soon as Internet connectivity is available. This functionality has been documented before [36, 37]. Two conditions were identified for this affordance: centralized (configuration) data management is a prerequisite including release and deployment management. An additional condition was that software development investments into the HMIS core software were made by MSF to make it more robust and improve offline functionality [36], a feature selected to be generic and relevant across

countries and use cases to be included for all users of the software [26]. At least a minimal level of Internet connectivity is required, which is not the case for every project. The outcomes indicated are that more iterative and selective configurations of the healthcare service monitoring were made possible, as teams do not need to wait for yearly updates to the metadata. It also led to increased front-line team independence and data ownership [37]. The benefits of this implementation did not go unnoticed across other OCs. The implementation led to, and is led by, an alignment of resources between the OCs related to the platform's core software. Additionally, deployed infrastructure is aligned in terms of the major and minor software versions to minimize the potential for software incompatibilities and bugs between the central instance and deployed local servers. Parallels to a mechanism within HMIS in LMICs identified by Gebre-Mariam and Bygstad [14], termed 'informatization mechanism,' can be drawn. In the paper, they lay out the causal relations of the digitalization strategy of a national (Ethiopian) HMIS. Structural entities of data volume and variety as well as a HMIS reform of paper-based approaches led to a standardization (across datasets and procedures), an integration (single source for data, one report channel) and an unrealized optimization targeting to 'create value from data' (enhanced insight, decision-making and process automation) [14].

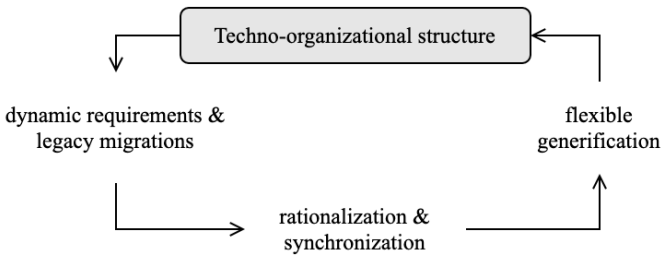

Fig. 9. Standardization mechanism

The abstraction of these two affordances informs this mechanism, depicted in Figure 9. The dynamics of the humanitarian context allows for fast-changing requirements and migrations to emerge; a rationalization of the IS content and subsequent synchronization occurred. They lead to the emerging standardization of configuration and software, thus a flexible generification: "work processes and actual use determine standards which are adapted pragmatically" [15]. This standardization strategy matches the highly dynamic humanitarian settings. The focus on working solutions from the bottom-up leads to lower complexity and increases the ability for ICT-based healthcare service innovation [15].

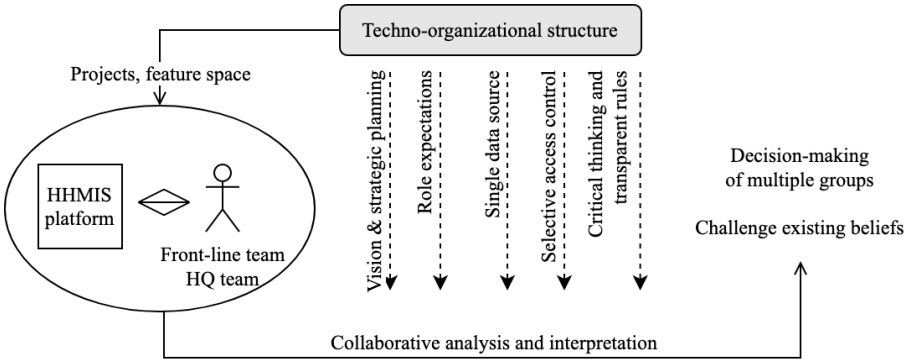

Fig. 10. Collaborative analysis affordance

6.3 The collaborativity & mobility mechanism

The third mechanism is described via two not fully actualized affordances. These have not yet materialized because the technical feature of the HHMIS platform is not yet available, or it is not implemented across and promoted within the organization due to limited feature availability.

The first affordance relates to the ability to collaboratively analyze data directly within the HHMIS. The enabling condition is an organizational need to discuss project-based data for strategic decision-making and the feature space provided by the HHMIS. A systematic literature review by Penn and Dent identifies ten either technical or social factors that must be enhanced in a balanced approach and in a certain order to attain effective decision-making within an organization [29]. Parts of the technical factors are not fully covered (for example, the HHMIS is not the organization-wide data warehouse but the monitoring platform); however, the social factors are deemed relevant: a strategic vision, planning and related dialog, individuals expressing their critical thinking and the setting of transparent rules for the discourse are conditions for collaborative analysis. These factors can challenge existing beliefs through enabling decision-making within multiple groups. However, this is sometimes not the case as one interviewee stated (INT5): "they make decisions and then look for data to back up their decision, but they don't use the data to make decisions. So we are trying to do change that so that they do it the other way around." Different roles within the organizations should be accounted for—for example, medical referents who oversee projects do not need, or are not expected to have, the same ability than front-line teams entering data. The features should help to explain and contextualize data with others, i.e. the analytical objects presented within the interpretation tool-set. One of the obstacles is a lack of access control, as an interviewee noted (INT5): "I'm in the capital, and I put you in a comment about the project. The person who is tagged in this thread can see the data from other projects who shouldn't have access." Having said that, this can be necessary when multiple groups discourse about a problem based on data.

The second affordance relates to the ability to easily access data on mobile devices. The current generation of mobile apps that seamlessly integrate with the platform focus on data collection. Interactive data analysis on mobile devices is not provided as a built-in feature, and the mobile application for accessing pre-made analytical objects has been deprecated (marking the end of official support and development). Thus, this affordance is not actualized.

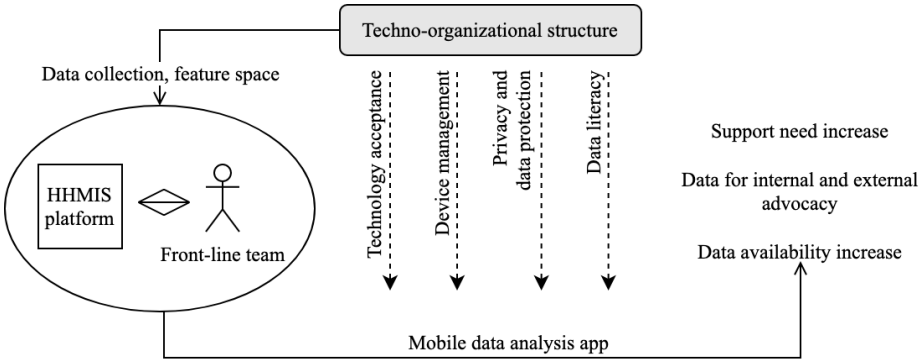

Fig. 11. Mobile analysis affordance

The enabling condition is that data is collected and available through the platform and the feature space provided by the platform. A stimulating condition, based on previous research on technology acceptance, indicates that the conjunction of well-informed technology design, perceived usefulness and perceived ease of use will increase the intention to use mobile health applications [24]. Mobile device management is required to efficiently administrate a large number of phones or tablets. Privacy and data protection measures must be in place, especially in regard to personally identifiable information of patients. In order to use a mobile application effectively, a certain data literacy is required. The outcome in theory would be increased data availability in the field: larger devices, such as personal computers, do not need to be carried around anymore. One interviewee (INT3) stated: "... we cannot expect them to bring the laptop. I think that would be way easier with a tablet [...] That's why the paper works better, because they put the paper in the pocket, because they would use it anytime. So I think anything that tries to be similar to paper in that sense, or to a notebook, would work." Mobile devices can be more easily brought to meetings or training sessions with internal staff but also external stakeholders, for example during meetings with staff of the country's Ministry of Health, "to make it a bit more interesting for everyone to know, to give an idea what we are doing" (statement of INT4). This advocacy is enabled as soon as a certain level of interactivity with data and the counterpart is required. It can be expected that one of the outcomes is an increased need for individual user support and

training as more devices are in use that need to transmit data. It also requires substantial institutional investments in hardware and software.

This mechanism is informed by two not-actualized affordances due to unrecorded contextual conditions [7]. The feature space and organizational strategy allow a mobile and collaborative analysis, which in turn enhances the social discourse for evidence-based decision-making. However, both require a minimal level of connectivity to the Internet to be minimally operational. Another structural aspect is the sustainability when collaborating with local institutions, as one participant noted (INT4): "with the [advantages of the] digital, the sustainability is a problem, because once we leave they [the Ministry of Health] will not maintain all this, and with all the updates of the software I don't think it will work when we leave... they are back to paper." Thus, this mechanism promises to increase the internal collaboration but is limited in its discourse with local, "external" institutions.

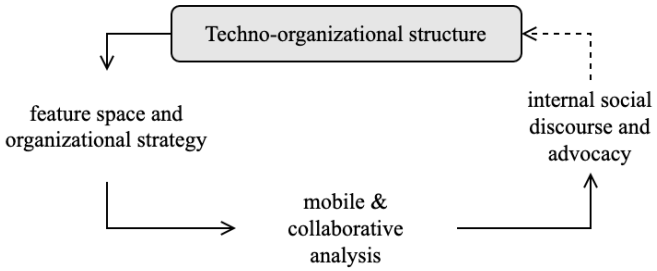

Fig. 12. Collaborativity & mobility mechanism

6.4 Mechanism interactions

Since three identified mechanisms emerge within the same context, through the same platform but with multiple teams, reasoning on how these mechanisms might interact based on the conditions and outcomes of them is a possibility. A listing of the mechanisms and related affordances is found in Table 3.

The interaction of the mechanisms is visualized in Figure 13. For improved readability, the mechanisms are formatted in *italics*. The *standardization* mechanism (the quantified use, lean content, generification and synchronized distribution) positively influences the *analytics service* mechanism (more specifically, the enabling conditions of its affordances: shared accountability, responsibility and feature space). The *analytics service* in turn enables the *collaboration* on the provided dashboard and dashboard items as well as the usage of the same dashboards on a (not available) new or integrated *mobile* application.

The additional internal social discourse on data can again be input to the mechanism of *standardization* (institutional capabilities and processes). How-

Table 3. Mechanisms and related affordances

Mechanism	**Affordances**	**actualized**
Templated analytics service	Templated analytical object provision	yes
	Adaptation of provisioned analytic tools	yes
Standardization	Rationalization	yes
	Synchronization	yes
Collaborativity & mobility	Collaborative analysis	no
	Mobile data analysis	no

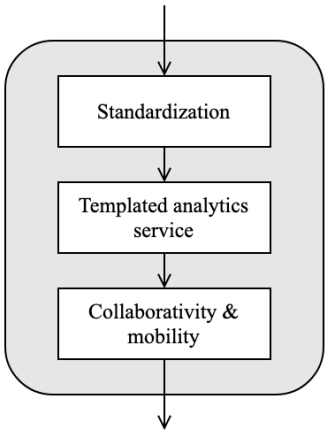

Fig. 13. Mechanisms interaction

ever, the influence of the *collaborativity & mobility* mechanisms was not further studied due the limited empirical evidence of non-actualized affordances.

7 Discussion and practical implications

The application of critical realism and affordance-based data analysis have helped to explore a limited set of issues in humanitarian health management information systems. This study pointed to three mechanisms in operation that influenced digitalization efforts and the use of information in project monitoring. A summary of the definitions of the identified mechanisms are given in Table 4.

Table 4. HHMIS mechanisms

Mechanism	**Definition**
Templated analytics service	The processes of providing templated analytical objects by intermediary digital health experts to frontline staff leading to relationships of users, producers and providers of data and related analysis tools.
Standardization	The process of dynamic requirements and legacy migrations inform a rationalization of IS content and concomitant distribution via synchronization leading to a standardization strategy of flexible generification.
Collaborativity & mobility	The process of strategizing the feature space for mobile and collaborative data analysis for increase in internal social discourse and advocacy.

The mechanisms identified in this study provide arguments for strategic developments and further research.

First, further research in the provision-use relationship of the analytics service is reasonable, as making "the system easy to use" is one factor in achieving greater acceptance [24]. Additionally, it might prove beneficial if a solution can help solve the contradictions between time constraints of front-line staff and required maintenance of analytical items in order to improve the efficiency for decision-making. One path for further research is predictive analytics which—in theory—reduces the time necessary for human input in decision-making [18].

Second, continuing the strategy of flexible generification is recommended as it is the most innovative standardization strategy [15]. Furthermore, the synchronization affordance is a closer step towards ICT-enabled real-time data (RTD) systems. RTD systems facilitate tactical adaptive management (iterative corrective action in program implementation), which acknowledges that changes are inevitable and programs might need to be altered in response to unexpected forces, especially in humanitarian work [3]. RTD systems, however, are currently limited in their ability to inform most strategic adaptive management as neither the timely provision of data nor accuracy of data determines adaptive success [3].

Thus, further research into the enablers and barriers of information use within RTD systems is necessary.

Finally, the development and use of platform-based collaboration tools in combination with mobile analysis technology that is closer to the front-line teams is a promising area for further research and development.

8 Conclusion

This study explored the generative mechanisms in a globally operating humanitarian medical organization. It focuses on the outcomes, conditions and structures of information use for project monitoring, drawing on a critical realist approach. It posed the research question: *Which generative mechanisms contingently lead to effective use of information for project monitoring in international humanitarian medical organizations?* It identified three mechanisms through an aggregation or abstraction of six affordances. Through that, the study provided an implementation of a critical realist case study in IS research, specifically an application of the analysis framework by Bygstad et al. [7] to identify generative mechanisms. The research approach lays its focus on explanation and not prediction. Nevertheless, it is able to provide arguments for more research on analytic service relationships, real-time data systems and collaborative and mobile data analysis in humanitarian health management information systems.

Aid organizations act in highly dynamic, complex and unpredictable environments and need to deal with transitions from immediate needs to long-term development. All throughout they are expected to prove their accountability and effectiveness. Here, data and information use cannot be isolated from the structures in which they occur. As irreversible life-or-death decisions are made based on increasingly digitized content, it is important to illuminate IS-related patterns and processes. The findings demonstrate that mechanism-based explanations can be useful in theory-building in IS research. The study attempted to build upon the existing but limited empirical evidence in humanitarian health information systems.

In building IS theory through the philosophy of critical realism, empirical generalization is considered valuable and often the first step for future studies [35]. The subsequent or parallel step of theoretical generalization is largely based on the process of retroduction: the logical argument explaining what conditions and structures must exist in order for the set of events to be enacted. In that way, the findings discussed in this study are not applicable to other settings (such as another organization) as the mechanisms (including their contingent conditions and structures) that cause the outcomes cannot be replicated. In place of prediction, the study provides insight into how and why a similar mechanism could lead to different (or similar) outcomes in a different setting [43]. As a summary, future research may take the findings from this study as material to evaluate similar or different mechanisms in humanitarian information systems. Additionally, the approach utilized in this study of conducting interviews, document reviews and affordance-based qualitative data analysis can provide methodological guidance

for practical implementations in other humanitarian organizations. Understanding the socio-technical patterns in their information system and wider context can inform strategic developments, for example through analysis and subsequent strengthening of identified conditions.

8.1 Limitations

A limitation of this study is the small interview sample size. During spring of 2020, in the midst of the COVID-19 pandemic, it proved to be challenging to find an international health organization willing to participate in a case study with interviews. Additional interviews, for example in other OCs or more front-line staff, would have fostered the internal validity of existing findings or made mechanisms less relevant in light of causally more stringent mechanisms, as only the mechanisms that have the strongest explanatory power and empirical evidence are to be explored further [7, 43]. Nevertheless, it is argued, the findings—identified affordances and generative mechanisms—as well as the methodology both provide material for reasoning about explanations of phenomena in humanitarian health information systems.

Conflict of interest

The author has no conflict of interest to declare.
Full disclosure: the author declares that he was a contractor with a company that provides ICT services (BAO Systems) to the organization under study (MSF) prior to the start of his Master's program. The company helped to provide access to key informants but was otherwise not involved in this study in any other form. The author also declares the intention to be a contractor again with the company after submission of this thesis and successful graduation.

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