From the DEPARTMENT OF GLOBAL PUBLIC HEALTH
Karolinska Institutet, Stockholm, Sweden

ON PEOPLE, DATA AND SYSTEMS - PERSPECTIVES ON ROUTINE HEALTH DATA PROCESSING AND ITS DIGITALIZATION IN TANZANIA

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Stockholm 2023

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Published by Karolinska Institutet.
Printed by Universitetsservice US-AB, 2023

ISBN 978-91-8017-020-8
Cover illustration: *Maternity care providers completing smart paper technology forms and facility registers*. Photo credit Aziz Ahmad, adapted by Stefanie Henke

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Thesis for Doctoral Degree (Ph.D.)

By

Regine Unkels

The thesis will be defended in public at Inghesalen lecture hall at Karolinska Institutet Stockholm and via Zoom, 6th of October at 09:00

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To all health care providers and their managers who care for their patients, day in, day out, all over the world.

"Data sometimes defies gravity because it goes up but doesn't come down…"

Dr. Mpoki Ulisubisya, Permanent Secretary of Tanzania's Ministry of Health, Community Development, Gender, Elderly, and Children (in Arenth, B et al. 2017. Defining and building a data use culture. PATH)

Popular science summary of the thesis

Across the globe, nurses, midwives and doctors provide services for pregnant women at health facilities and collect routine health data about these health care encounters. They document information such as the number of mothers seeking antenatal care and the proportion of women with high blood pressure receiving medication. This data allows health care managers to make decisions about staff levels, equipment and medication needs which ensures effective management of health care services.

While high-income countries use computer systems to enter and process data, countries with fewer resources, such as Tanzania, use register books, entering patient information by hand. Summary data, which is calculated every day and at the end of each month, is then entered into a computer software called District Health Information System-2 by another individual. During the data collection process, there is a risk that health care providers or data managers make errors with regard to i) entering patient data into the register or ii) calculating the summary, and iii) entering data into the computerized system. Missing data or data reporting errors lead to low quality of data. Health care managers or politicians may consequently hesitate to use it to make decisions.

With digital technology, the calculation and data transfer processes are automatically carried out. The resulting improved data would allow a country such as Tanzania to allocate resources more effectively. One example of a promising digital tool is Smart Paper Technology. Health care providers complete a paper form when a pregnant woman seeks antenatal care, gives birth, or receives care after birth. Each form has a bar code and a unique patient number and can be scanned with a regular copy machine. The information is then automatically entered into computer software.

However, research suggests that the environment into which a new digital technology is introduced affects how successfully it is integrated into the existing system. Factors that can affect this include: i) The way health care providers work together, ii) how the hospital management is promoting the new technology and iii) what laws are in place to support the use of digital technology.

This thesis aimed to understand the social practices involved in collecting and processing routine maternal and newborn health data in Tanzania and how these might influence digitalization. Smart Paper Technology introduction and the current routine health data processing system, with its different digital components, were the focus of this research.

For the **first study**, health care providers and health care managers from three health facilities in Southern Tanzania were asked about their perceptions of Smart Paper Technology. The amount of time that they spent on collecting routine health data before and after the introduction of the new system was also measured. No difference was seen in the time spent on data collection, but health care providers did spend more time with clients after the technology was introduced. They found Smart Paper Technology easy to use and applicable to their context. In contrast, health care managers found it difficult to identify benefits for their own work from the new technology. This was related to problems accessing the digital registers and data summaries. They also had doubts about the quality of Smart Paper Technology data. They therefore continued to focus their efforts on the existing health management information system.

The **second study** used Smart Paper Technology and District Health Information System-2 data from 13 health facilities in Southern Tanzania to measure aspects of data quality over 12 months, with the aim of assessing whether the data was of comparable quality. Results showed that data quality of the Smart Paper Technology system was not as good as in the current system overall. Smart Paper Technology performed slightly better with regard to the level of conflicting information within the overall data (consistency), but the District Health Information System 2 showed better quality for all other aspects, such as data completeness, timeliness and comparable data trends over the study period.

The **third study** used 1) interviews with health care providers from maternity wards in two rural hospitals, 2) observations of the work carried out in these two wards, and 3) group discussions with health care providers. The aim was to gain understanding about the type of data that nurses, midwives and doctors need and how they perceive and use data in general. Findings illustrate how health care providers used data from the official routine health data system and other documentation sources to maintain good relationships with managers and the community they served. Data helped them to show their professionalism in a working environment that was often not conducive to good service delivery.

For the **fourth study**, health care managers working at 1) ministerial level and 2) district and regional health authority level in Tanzania were interviewed to gain more knowledge about their experiences and perceptions related to data, data systems and the use of digital technology. Findings show that these managers led implementation either by using the power assigned to them through their position (institutional power), or by interpreting policies in a way that made these applicable to the given context (discretionary power). Discretionary power use was a response to an unpredictable working environment with uncertain financial resources, and staff lacking the necessary skills to collect and process routine health data of consistently good quality.

Conclusions

Routine health data collection and processing is characterized by high levels of unpredictability and uncertainty due to the difficult environment in which it takes place.

This leads to the need for rearrangements of interactions between managers and health care providers and of activities related to routine health data collection over time in response to changes in the environment. The environment of routine health data collection and processing is therefore important for its smooth running and the successful integration of digital technology.

A popular science summary in Kiswahili can be found in the appendix of this thesis.

Abstract

Background

Facility-based routine health information is captured in health management information systems by health care providers and is the main data source for health system planning and outcome monitoring in Tanzania and other low- and middle-income countries. While this system is fully digitalized in high-income countries, it is still partly paper-based in others. These use i) facility registers, ii) daily tally sheets and iii) monthly summary forms, which are later entered into the District Health Information System-2 software. These hybrid systems are prone to errors related to i) data entry, ii) calculation and iii) data transfer, with negative implications for data completeness and availability. The unavailability of data and lack of trust in its quality may lead to low data use for resource forecasting and planning, especially at subnational and facility levels. Through automatization of data processing, digital technology may be able to address these challenges, making it especially attractive in settings with high disease burdens and few resources. One example of a promising digital solution for low-resource settings is Smart Paper Technology, which produces automated electronic registers and summary reports by scanning bar-coded forms from individual service encounters. Implementation research, however, suggests a complex interplay between the implementation environment and the introduction and sustained institutionalization of technology.

The **aim** of this thesis was to understand the social practices involved in generating and processing routine maternal and newborn health data, using paper-based and digital tools within the health management information system in Tanzania. Smart Paper Technology and the current health management information system with its different digital components are used for evaluation.

Study I had the objective of understanding health care providers' and facility/district managers' perceptions of Smart Paper Technology and to assess time spent on documentation with the new system. A time-motion study, before and after the introduction of the technology, was applied together with eight focus group discussions with 18 health care providers from three health facilities and 11 in-depth interviews with healthcare managers from one district authority. Quantitative data was analyzed using descriptive statistics and bivariable modelling. Reflexive thematic analysis was used to analyze qualitative data. Findings illustrate challenges to Smart Paper Technology implementation related to pre-existing health system bottlenecks, e.g. lack of human resources, supervision and transport, but also a difference in values assigned to the new system by health care providers and their managers. Health care providers found Smart Paper Technology useful and applicable to their context with perceived benefits for documentation and clinical care. These experiences were confirmed by quantitative data, showing no significant difference between time spent on overall documentation pre- and

post-introduction of Smart Paper Technology (27 vs 26 %, adjusted p 0.763) but an increase in time spent on clinical tasks (26.9 vs 37.1%, adjusted p 0.001). Health care managers, in contrast, found it difficult to identify benefits from the new technology for their own work related to national reporting, due to access problems with the digital dashboard and questionable quality of Smart Paper Technology data. They therefore continued to focus managerial efforts on the existing health management information system.

Study II's objective was to assess the quality of Smart Paper Technology data for maternal care services related to i) completeness and timeliness and ii) internal consistency. A cross-sectional survey over 12 months was performed in 13 health facilities using data from the Smart Paper Technology system and District Health Information System-2. Descriptive statistics were produced based on indicators derived from the World Health Organization's Data Quality Review Toolkit.

Results show that data quality of the Smart Paper Technology system was not superior to that of the pre-existing health management information system overall. This may be linked to the effects of duplicate data entry on health care provider performance and consequently on data completeness. Smart Paper Technology performed slightly better in some aspects of internal consistency: Fewer health facilities produced only one or two outliers with Smart Paper Technology in each month of the study period (antenatal care=4, care during labour = 6, postnatal care =4) than with the District Health Information System-2 (antenatal care= 7, care during labour= 9, postnatal care= 6). Smart Paper Technology also yielded higher consistency for the documented postpartum use of oxytocin in relation to the number of documented deliveries with 62% of facilities showing a less than 10% difference between these indicators as opposed to 38% for the District Health Information System-2. However, the pre-existing system demonstrated better data quality in all other quality dimensions, i.e. data completeness, timeliness and consistency of data trends over the study period.

Study III: The objective was to improve understanding about the processes involved in health care providers' data use; which type of information is used together with health management information system data and for what purposes. A constructivist grounded theory-based ethnographic approach was applied, consisting of i) 14 in-depth interviews with health care providers from maternity wards in two hospitals, as well as ii) 48 hours of observation in the maternity wards and ii) two focus group discussions with 11 health care providers from the same hospitals.

Findings illustrate how health care providers appropriated numeric data from the official health management information system and narrative data that they had produced for clinical documentation to safeguard social relationships with superiors, patients and the community they served. While they identified themselves as data collectors and not users of the health management information system, they applied narrative clinical documentation systems to service improvement and to protect themselves against litigation or managerial reprimands.

Study IV's objective was to generate knowledge on experiences and perceptions of health care policymakers in Tanzania related to data, data systems and the implementation of digital technology to support health information management. 16 in-depth interviews with healthcare managers from national and subnational levels were conducted and analyzed using reflexive thematic analysis.

Results suggest that the health management information system in Tanzania is governed using institutional and discretionary power. Institutional power was mainly used at the national level to conceptualize data collection and processing systems and the scale-up of digitalization. Discretionary power was mainly used for implementation at subnational level. The use of different power practices was influenced by available funding and health care managers' perception that health care providers, the primary data collectors, lack motivation to perform and are unpredictable in their actions regarding the continuous production of good data quality.

Conclusions

Acceptance or rejection of digital technology was influenced to a considerable extent by social practices at all levels of the health system. These included actors' perceived benefits of maintaining existing social practices. These practices, which are part of an organization's culture related to data and data processes, require attention during the conceptualization and implementation of health information systems. Numeric and contextual information is used concomitantly at various levels of Tanzania's health management information system. The health management information system in Tanzania forms a complex adaptive system with inherently high levels of unpredictability, non-linearity, self-organization and adaptation over time. Health care managers' power practices in the conceptualization and implementation of policies reflect this complexity.

Contextual factors affect digital technology integration and have consequences for data quality and use of digital AND paper-based health management information systems. Context may therefore be even more important than the format and technology of data collection and processing.

List of scientific papers

I. **Unkels R**, Manzi F, Kapologwe NA, Baker U, Ahmad A, Nabiev R, Berndtsson M, Baraka J, Hanson C and Hirose, A. Feasibility, usability and acceptability of a novel digital hybrid-system for reporting of routine maternal health information in Southern Tanzania: A mixed-methods study. *PLOS Global Public Health*. 2023; 3(1): e0000972 [DOI: https://doi.org/10.1371/journal.pgph.0000972]

II. **Unkels R**, Ahmad A, Manzi F, Kasembe A, Kapologwe NA, Nabiev R, Berndtsson M, Hirose A and Hanson C. Caught in the data quality trap: A case study from the evaluation of a new digital technology supporting routine health data collection in Southern Tanzania. [Manuscript]

III. **Unkels R**, Alwy Al-beity F, Julius Z, Mkumbo E, Pembe AB, Hanson C and Molsted Alvesson, H. Understanding maternity care providers' use of data in Southern Tanzania. *BMJ Global Health*. 2023; 8(1): e010937 [DOI: doi:10.1136/bmjgh-2022-010937]

IV. **Unkels R**, Mkumbo E, Kapologwe NA, Manzi F, Hanson C, Mølsted Alvesson H and Pembe AB. "Implementing a policy is something else". A case study on governance of complex health information systems in Tanzania. [Manuscript]

Contents

List of abbreviations

AKU	Aga Khan University
ALERT	Action Leveraging Evidence to Reduce Perinatal Mortality and Morbidity in sub-Saharan Africa
ANC	Antenatal Care
CAS	Complex Adaptive System
DHIS-2	District Health Information System-2
DQR	Data Quality Review
EMR	Electronic Medical Records
FGD	Focus Group Discussion
GoT	Government of Tanzania
GoT-HoMIS	Government of Tanzania Hospital Management Information System
HIS	Health Information System
HMIS	Health Management Information System
HSSP	Health Sector Strategic Plan
ICT	Information and Communication Technology
IDI	In-depth Interview
IHI	Ifakara Health Institute
MoH	Ministry of Health
MUHAS	Muhimbili University of Health and Allied Sciences
NASSS	Non-adoption, Abandonment and Challenges to Scale-up, Spread and Sustainability of Technology-supported Change Efforts in Health and Social Care
NPT	Normalization Process Theory
PNC	Postnatal Care
PO-RALG	President's Office for Regional Administration and Local Government
PRISM	Performance of Routine Health Information System Management
SPT	Smart Paper Technology

TA	Thematic Analysis
TDHS-MIS	Tanzania Demographic and Health Survey and Malaria Indicator Survey
TMS	Time Motion Study
WHO	World Health Organization

Definition of key terms

Key terms	**Definition**
Health Information System (HIS)	An *"integrated effort to collect, process, report and use health information and knowledge to influence policy-making, programme action, and research"* (1)
Health Management Information System (HMIS)	*"A system of service-generated data derived from facilities and patient–provider interactions covering aspects such as care offered, quality of care and treatments administered"* (2) as part of the HIS.
District Health Information System 2 (DHIS-2)	*"The **software** to collect, analyze and access data within the HMIS" in* Tanzania (3)
Routine health data	Data collected at facility level during health care provision for every client-provider encounter
Facility registers	**Paper-based** HMIS registers to collect data on health care provision to individual patients used in all departments of a health facility including maternal health care. Individual data is summarized daily in paper-based tally sheets.
Facility summary reports	**Paper-based** HMIS forms to calculate monthly data summaries for each facility department including maternal health care.
SPT forms	**Paper-based** forms for manual data collection on health care provision for individual patients. One form is completed for each client-provider encounter. The **equivalent for HMIS** at facility level is the individual data entry in a row of the **facility register**.
Digitalization	The transfer of previously manual steps of data collection or processing to digital formats
Digitization	The transformation of paper-based data into electronic data

1 Preface

I acknowledge that I did not come as a blank page to this research. Like all humans, I have my personal view of this world, its people and their interactions. Most of my views related to health care and its documentation were formed during my medical training, the writing of my thesis for a German doctorate in medicine and my work within the German Development Cooperation in Tanzania. During my career, I have worked with different professional cadres in different settings. These include traditional birth attendants in Burkina Faso; paramedics, nurses, midwives and doctors in Germany, India, Burkina Faso, Tanzania and England; and research participants in Tanzania.

I am a medical doctor, but obstetrics has been my passion from very early on. My second passion, developed during my student days, is medical anthropology and participatory methods for the empowerment of rural communities. In 1994 I got the opportunity to carry out my thesis for the German medical licentiate degree in Séno province in Northern Burkina Faso. The focus was on the early detection of pre-eclampsia and eclampsia, a pregnancy complication with high mortality. Not many women in Séno came to a health facility for antenatal care in those days, but almost every village had a traditional birth attendant. My research project included teaching traditional birth attendants from 24 villages to detect pre-eclampsia and eclampsia and monitor how they were faring regarding diagnosis and referral over one year. What I enjoyed most, was interacting with these birth attendants and listening to descriptions of their indigenous concepts of eclampsia and childbirth in general. I realized that their worldview was not so far from the biomedical paradigm I was trained in, since biomedical science could also only provide hypotheses on the pathogenesis of this disease, which had changed considerably over time. Although my experiences working with the traditional birth attendants of Séno province spurred my love for medical anthropology, my work as an obstetrician and gynaecologist in the following years continued within the biomedical paradigm. I am most grateful to be able to integrate anthropology into my work once more!

My first appointment as a trainee in obstetrics and gynaecology in Germany was in the hospital where the first digital perinatal registry was developed. Initially, we medical doctors had the task of entering data after every delivery. Carrying out his task at three o'clock in the morning was no fun and over time, it was shifted to the midwives all over Germany. I still ask myself, how this happened. Was it, because they were more in numbers or because the medical profession had more power to say "no" to this task? Many years later, I worked for the German Development Service as a clinician and advisor to the regional HIV/AIDS team in Lindi Region, Tanzania. I witnessed how health care providers, especially the nurse-midwives in labour wards, were struggling with their working environment, often failing to balance their work tasks. Routine health data collection was quite obviously an additional burden to them and was often moved to the back of their priority list.

Health care is very difficult work, even in places where resources are plentiful. I am always amazed at how health care providers make things work for their patients, themselves and their managers, despite their challenges. But what has puzzled me the most wherever I worked, is how people describe what they do (or would do) and then go on to do something different. I also asked myself what health care providers (including myself) would need to be able to wholeheartedly take on routine health data collection, not only as part of their job but as part of their professionalism. These queries remained with me until I had the opportunity to write this thesis.

2 Background

The World Health Organization includes a well-operating health information system (HIS) in its six building blocks for health system strengthening. This is to ensure that high-quality data is collected, processed and used to monitor health system performance, a population's health status and health determinants (4) (Figure 1).

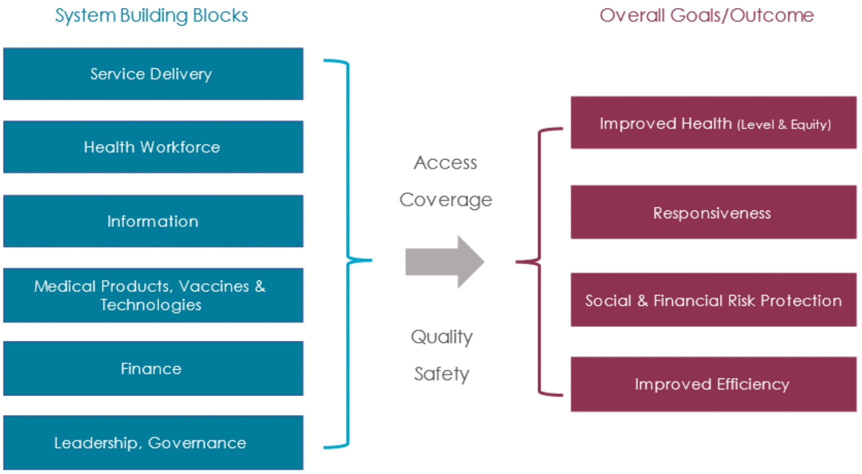


Figure 1 The health system framework

Reproduced from World Health Organization. Everybody's business: Strengthening health systems to improve health outcomes: WHO's framework for action. 2007. p3. ISBN 978 92 4 159607 7 with permission from the World Health Organization. © World Health Organization, 2007.

Since the 1990s, the global health community has increasingly committed to the joint monitoring and achievement of health-related indicators, including maternal and child health indicators, to improve health status, access and health care provision globally (2, 4-7). The Millennium Development Goals and later Sustainable Development Goals have delineated the paradigm of data-informed decision-making (6, 8, 9). Quantitative data, also called numeric data, is used to construct comparable indicators for the delivery of health care in a broad variety of settings. These indicators aim to hold governments, health systems and their staff accountable for and committed to the agreed goals and assist funding organizations to decide where to invest limited financial resources with the greatest returns (5, 10). Maternal and child health are categorized under the Sustainable Development Goal 3: Health and Wellbeing (6). A slow global decline in maternal mortality by an average of 2.1% per year only between 2000 and 2015 (11) has put maternal health on the international agenda and sparked an increased interest in the measurement of maternal mortality itself and of factors associated to maternal health care (7), like skilled birth attendance, or facility-based deliveries.

While data for these indicators is collected within the health care system, actors from the same system are also meant to use data for planning and prioritization at subnational and national level (12-14) and for performance monitoring, commodity forecasting and service quality improvement at facility level (15-17).

2.1 Components of health information systems

An HIS involves all processes related to data collection, processing and use for decision- and policymaking (1) and, according to the Health Metrics Network, consists of six components:" i) Resources, ii) indicators, iii) data sources, iv) data management, v) information products and vi) dissemination and use" (18) (Figure 2). The data sources contributing to this system in turn inform the sub-systems used in Tanzania. They consist of i) population-based and ii) institutional data sources, the latter being relevant for this thesis. Routine data from health care provision is collected in the health management information system (HMIS) (Figure 2).

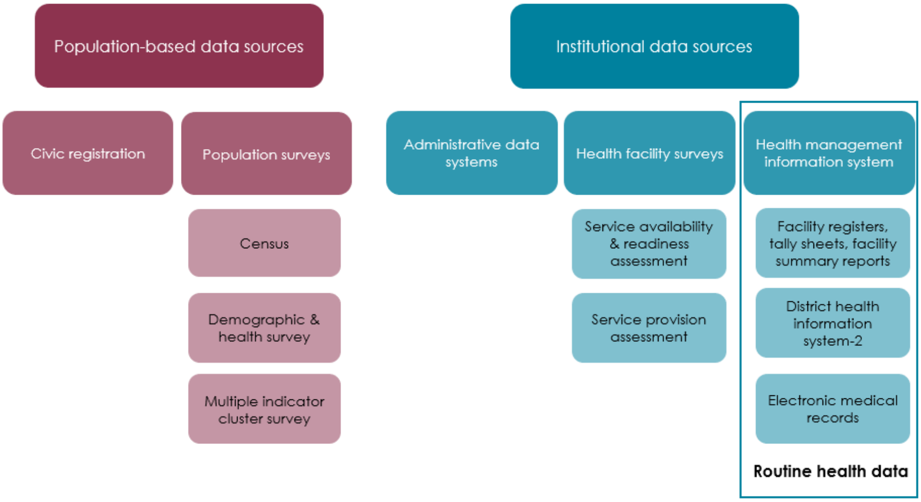


Figure 2 The health information system

In countries like Tanzania, data collection for the HMIS usually involves paper-based facility registers (or HMIS registers), together with daily tally sheets and monthly facility summary reports. The latter are then manually entered into the District Health Information System-2 (DHIS-2) software either directly at the health facility or at district level (3) (Figure 3).

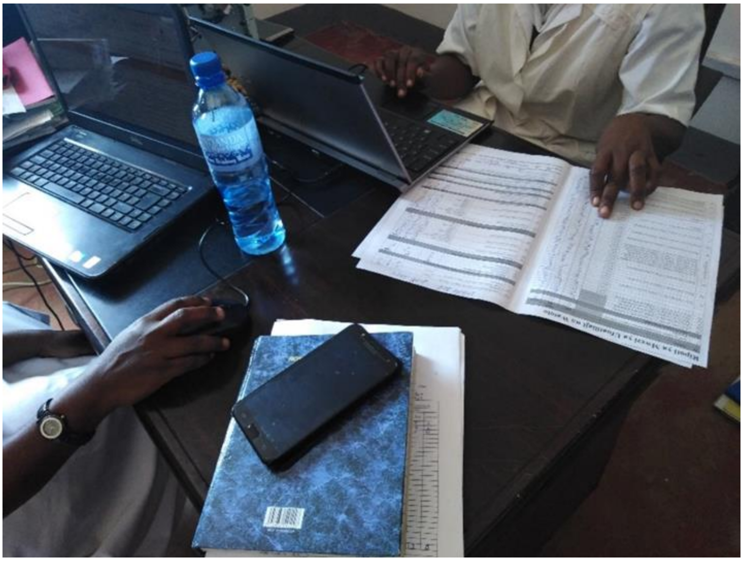


Figure 3 Manual data entry of summary reports into the District health information system-2

2.2 Health management information systems

The origins of basic health statistics date back to the 17th century, a time when infectious diseases were prominent in Europe and surveillance was deemed necessary to curb their spread (19). Soon after, several Western European countries started to collect continuous health data on their population (2). Facility-based data systems became available much later in the 1980's and the first of these were designed for administrative purposes, e.g. to follow up on financial returns or for patients' appointment booking (20, 21). While electronic medical records (EMR) have taken over routine health data collection in high-income countries, HMIS remain the cornerstone for health care monitoring and planning in settings with limited resources like Tanzania (22-24).

As outlined earlier, HIS comprise population-based and institutional data sources, the latter containing routine health data collected during each clinical encounter at health facility level (Figure 2). This data is captured in the HMIS (18) which is the focus of this thesis. The HMIS constitutes the main data source for decision-making at facility and district level, since data from population-based surveys or health facility-based surveys is only available periodically, and at an aggregate level. HMIS data, in contrast, is continuously collected and of low cost. Its disadvantage is, however, that it cannot provide information about problems (and opportunities for that matter) occurring outside health services. Still, most scholars and implementers argue that HMIS data is a convenient and appropriate data source for health care monitoring, decision-making and planning (24, 25).

It is of note that HMIS data, in contrast to survey data, is collected by health care providers and not by trained data collectors. In addition, this data is captured during clinical care and not at a time that is dedicated to data documentation only. Both have a bearing on the quality of routine health data.

2.3 Challenges to HMIS data quality and improvement strategies

Forfeit et al. argue that data demand, quality and use are intrinsically linked to each other and that an improvement in one component must lead to an improvement in the other two (26). This data demand and use framework constitutes the rationale given by many scholars and implementers in first focusing on improving data quality to increase subsequent use (26-28).

There is ample research on the data quality of HMIS in Tanzania and other similar countries (14, 29-37). Study results, however, vary depending on the method of assessment used and the operationalization of data quality dimensions (38). In 2017, the WHO launched a data quality review (DQR) toolkit with defined data quality dimensions, metrics and indicators. Its purpose was to improve comparability and facilitate regular quantitative data quality assessments so that facilities and districts could identify trends that can be subjected to improvement measures (39-41). DHIS-2 now contains a data quality review function based on WHO's tool kit, which can be used at all levels of the health system.

In Tanzania, research findings have shown marked data inconsistencies between facility registers, tally sheets, monthly facility summary reports and DHIS-2 data. Some registers were incompletely or incorrectly filled, tally sheets were used inconsistently, and reports tended to overstate numbers (e.g. of patients treated) as compared to registers. This translated into a similar trend in DHIS-2 (29, 30, 37). Data quality also varied by facility department, i.e. wards with many patients and many indicators to be collected, performed worse than services with only a few patients and indicators (30). Factors reportedly preventing good quality HMIS data in Tanzania included i) low health care provider numbers, ii) limited resource availability, e.g. registers or forms, iii) infrequent supervision, iv) lack of feedback loops and v) parallel documentation in other data systems (15, 42). This is in line with other studies from similar settings, e.g. Ethiopia or Malawi (32, 33, 43, 44).

While most studies report low performance of the HMIS related to data quality, researchers have also identified good practices that may improve it. Lemma et al. reported in a scoping review that i) regular data quality assessments, ii) digital technology use, iii) feedback and iv) capacity building through training or mentoring, improved data availability and subsequent use (45). The authors concluded that a combination of these measures yielded better results than introducing new technology alone (45). Other researchers have made similar suggestions (32, 33, 44). Although there seems to be agreement on “what” is needed to improve data quality, the “how” is less clear. This may partly be because facility-based data systems which include HMIS have “grown” organically instead of having been designed in one step to become what they are today, which makes them contextually variable. Furthermore, implementers fail to employ a system-design lens when conceiving interventions to improve data quality and use (46).

2.4 Challenges with HMIS data use and improvement strategies

Kumar et al. define data use as “all the processes that need to be applied to turn data into knowledge ready to be used for decision-making” (46). These processes include data analysis, synthesis and appropriate visualization. De Savigny and Binka argue that data itself is of little use for decision-making unless it is subjected to an analytic process turning it into information and subsequently into evidence and knowledge (47). “Making data speak”, they explain, needs human interaction with the data, i.e. health information management to translate, re-package and summarize the content for different user groups (47).

Research suggests that health care managers at sub-national and even national level in low-resource countries make limited use of routine health data during decision-making. Lack of analytic skills is put forward as one of the reasons for this finding (15, 48-51).

There is a paucity of research evaluating data use at facility level. The few existing studies reported that most facilities could not produce evidence that they were using data for decision-making or planning purposes. Lack of analytical skills was cited as one of the barriers here too (49, 52-55). These skills are not necessarily taught during clinical pre-service training and Nicol et al. found low competency related to data interpretation not only among South African health care providers, but also their managers and even HMIS-officers (56). Further research has echoed their findings (12, 44, 51, 57). Several studies have reported that primary data collectors feel disempowered when it comes to data use, claiming that they are producing routine health data for others, namely their managers, to use (42, 58, 59). Other prominent factors influencing data use described in the literature seem to reflect this “lack of agency”: i) leadership and system governance, ii) supportive supervision and participatory monitoring, as well as iii) mentoring and regular feedback (15, 32, 45, 53, 60, 61). This also suggests that individuals need substantial organizational support to successfully use the data they generate to improve health care service planning and delivery.

Since I started my research in 2019, several scoping reviews have been published, with the aim of documenting strategic approaches to improving data use and quality. All highlight the positive influence of leadership and health system governance for data use at lower levels. Authors stress the need for i) active engagement of leaders as role models in data use, ii) participatory approaches to follow-up on data quality and use and iii) feedback loops to lower-level managers and health care providers, leading to increased use of data at these levels. The authors also described providing opportunities for actors of the health management information system to actively engage with data together with the introduction of digital technology as important to foster data use (45, 60, 62). Emphasis was put on the importance of strengthening the capacity of health care providers to analyze and synthesize data. Rendell et al. claim that this has the added benefit of enabling a better understanding of the importance of data and data use, thus leading to transformative change among participants (60). In addition, they describe the use of qualitative data for triangulation, as part of a larger approach to data use, as providing helpful contextual "real-life" information to data users to make sense of quantitative data (60). Other individual studies have confirmed the scoping reviews' findings regarding the importance of leadership and the provision of regular opportunities for different users to review and discuss data. They have also highlighted the importance of increasing staff levels, professionalization of data collection and processing through the employment of specialized staff (44) and emphasized the link between data quality and use (51). Busza et al. have described the high degree of support through formal training, mentoring and coaching, that high-level decision-makers in Ethiopia needed to transform their data use habits (63).

While the scoping reviews mentioned above, emphasize the importance of combined interventions to address individual, organizational and technological issues, Byrne et al. state that most of the articles included in their review, primarily addressed technological problems, although these constituted a minority of the challenges identified (62).

2.5 Digitalization of health management information systems

The problems associated with data quality and, to some extent, data use may be addressed by full digitalization of health management information systems. Research suggests that digital technology can improve i) data availability through automated processing, ii) appropriate visualization and iii) provide in-built data quality assessments. (57, 64, 65). In turn, these functions may support better system performance and possibly better data quality, which might foster increased data use (27, 45). In addition, system integration through digital interfacing can decrease duplicate data entry and thereby reduce health care providers' workload (66, 67).

2.6 Social dimensions of data and data systems

Despite the knowledge gained from implementation projects and research to improve data quality and use, with or without the application of technology, the questions of why the discrepancies in data quality occur and how health care workers use information remain largely unanswered. Rudinow Sætnan et al. argue that statistics are constructed from a distinct worldview of the society that generates them. They further acknowledge that the same principle applies to a society's choices regarding which aspects of life and society are not examined statistically (8). Thus, the counting and reporting of numbers also has social dimensions. Similar decisions on which data to include are also made for the generation of estimates constituting indicators, e.g. a maternal mortality ratio after an important amount of calculation as Wendland illustrates in her case study from Malawi (8).

Research has increasingly documented that discrepancies between the different HMIS tools may exist because routine health data is manipulated during documentation and processing (58, 59, 68). Research from Burkina Faso, Ethiopia and Tanzania suggests that health care providers alter data in the partograph or in registers retrospectively due to institutional pressure, e.g. because their immediate managers need completed partographs for their own reporting, or because managers focus on numeric performance indicators. This is also mentioned by Shamba et al. in a study from Tanzania, who reported that data completeness was valued over consistency by superiors (42). Estifanos et al. also describe how, in Ethiopia, overstating performance figures during documentation was regarded positively by healthcare managers (58). Wendland and Adams describe the political power that numeric information may have and assign this also to the notion that numbers, and therefore indicators, are considered to be neutral and truthful (5, 9).

2.7 Health information systems as a social entity: The role of organizational culture

Ideally prioritization in health care planning should be aligned to the needs of a population while using available funds efficiently (2, 69). Scientific literature suggests however that organizational challenges constitute major bottlenecks to the use of routine health data for decision-making on planning and prioritization. Lippeveld and others have coined the term information or data use culture to describe an enabling organizational culture that fosters positive shared values surrounding data collection, processing and use (27, 69, 70). The idea of influencing the social and cultural norms and processes of an organization surrounding data, to shape employees' action and interaction, is quite compelling.

In the Performance of Routine Information System Management (PRISM) framework (70), Aqil et al. describe information culture as one of several organizational determinants influencing data processes and ultimately system performance. The authors argue that understanding the shared organizational values around data systems may offer opportunities to influence these in a positive manner. The PRISM framework defines information culture as "the capacity and control to promote values and beliefs among members of an organization on collecting, analyzing and using information to accomplish the organization's goals and mission" (70). It mentions the following components as part of this organizational culture: i) Data quality, ii) data use, iii) evidence-based decision-making, iv) problem-solving, v) feedback and vi) responsibility, empowerment and accountability (70). Despite their argument that a positive information culture can improve data system performance, the authors state that not much is known about how these shared values develop in the first place nor how they can be maintained or changed, if necessary, to a more conducive set (70).

A number of publications have used the PRISM framework and its quantitative assessment tools to evaluate data quality and data use. Nicol et al. describe a lack of information-use culture as one of the barriers to information use for HIV-programming in South Africa (49). Ngusie et al. found a positive correlation between health care providers' perceived level of information use culture and their use of data in Ethiopia (53).

Other scholars have applied a similar "log-frame-type" model to data use culture: In their theory of change to accelerate data use, Arenth et al. hypothesize that a data use culture will evolve once certain pre-conditions are put in place, such as interoperability, investments, infrastructure, leadership and governance and an adequate workforce (27). The authors postulate, in their adjunct behavioral change framework, that a change towards a culture of data use is based on the individual change of different actors, but that it is the organizations responsibility to create a shared understanding and a vision among actors about the value of data for decision-making. The mechanisms for change are delineated as follows: i) An increased awareness of individual information needs, ii) access to the right information, iii) motivation and empowerment to use this information and iv) the capacity for information use (27).

In line with the dimensions of information or data use culture put forward by Aquil et al. (70) and Arenth et al. (27), several studies have described health care providers' negative attitudes towards data (34), their lack of commitment and motivation (26) and their resistance to change (10) as barriers to data quality and use. Tilahun et al. have applied the socio-ecological model to qualitative data on information use by health care managers in Ethiopia. They found that the value assigned to data, incentives, and aspects of an organizational culture related to data use were considered to be equally important for data quality and use at individual, organizational and inter-relational level (36). In addition, the authors describe how the health system failed to enforce accountability for false reporting, a situation that is also reflected in other qualitative studies from Ethiopia (58) and Burkina Faso (59).

2.8 An introduction to Tanzania

Tanzania, formally called the United Republic of Tanzania, is a country in East Africa, bordering Kenya and Uganda to the north, Burundi, Rwanda and the Democratic Republic of Congo to the west, and Malawi, Zambia and Mozambique in the south. To the east, its Indian Ocean coastline stretches between its borders with Kenya and Mozambique (Figure 4). This coastal area, together with the islands of Pemba, Unguja and Mafia, forms one of the three geographic areas of Tanzania together with the plateau and the highlands (71). The latter are mainly covered by savannah and secondary or primary forest.

Figure 4 Map of Tanzania adapted from National Bureau of Statistics by Stefanie Henke (Research area highlighted in petrol)

Today's mainland Tanzania was subjected to colonial rule by the German and British Empires from 1886 to 1961, when the Republic of Tanganyika achieved political independence. In 1964, the present state was formed under President Julius Kambarage Nyerere, based on Tanganyika's unification with the People's Republic of Zanzibar (71).

Between 1964 and 1985 the government's economic approach was defined by the concept of *Ujamaa*, or African Communalism, based on principles such as communal production and distribution, and egalitarianism within the smallest self-sufficient cell of the society, the village (72). The country became a market economy in 1985 under the *Structural Adjustment Programme* of the *International Monetary Fund* (71). In 2021 the country was ranked 160th out of 191 countries in the Human Development Index (73). The country transitioned to a lower middle-income status in 2020. Still, in 2021 44.9% of the population lived below the poverty line of 2.15 USD per day (74).

In 2022, Tanzania had a population of 61,741,120 with 65% living in rural areas (75). Women accounted for 51% of the population and 61% of the women and 63% of men are below the age of 25 years (75). The adult literacy rate in Tanzania was 82% in 2021. Women had a literacy rate of 78%, while the rate was 86% for men (76). Tanzania was ranked 146th out of 170 countries in the Gender Equality Index in 2021 (77).

Kiswahili is the official language of Tanzania and is taught in primary education and is universally spoken. English is taught only in high schools and at universities. Health care providers who are transferred outside their home region, thus hardly face language problems at their new posting, but this does not necessarily mean that they are fully aware of local customs and norms or accept these (78). Next to Kiswahili approximately 120 other languages are spoken in the country, mostly in specific geographic areas with their cultural peculiarities (71).

Life expectancy at birth in Tanzania was 66 years in 2021 (74) and the total fertility rate for 2017-2022 was 4.8 children per woman, with higher levels in mainland Tanzania (79). Recently a notable decline of maternal mortality point estimates was reported from 760 deaths/100,000 live births in the year 2000 to 238 in 2020 (11). According to the most recent Tanzania Demographic and Health Survey and Malaria Indicator Survey (TDHS-MIS), from 2021/2022 most women received four or more antenatal care (ANC) visits (65%) and 81% delivered in a health facility. Only 51% had postnatal care (PNC) within the first two days after delivery (79). There are regional variations in the facility-based delivery rate (94.3% in urban areas and75.9% in rural areas) (79, 80). Furthermore, women with higher education or from the highest wealth quintile were more likely to attend ANC four times or more, have an institutional delivery and receive PNC within two days postpartum as compared to women with no formal education or from lower wealth quintiles (79).

According to TDHS-MIS 2021/2022, child and infant mortality declined substantially since the last survey in 2015/2016: Under-Five mortality decreased from 67 deaths/1,000 live births to 43 and infant mortality from 43 to 33 deaths/1,000 live births. The decline of neonatal mortality was slow, from 25 deaths/1,000 live births to 24 deaths (79). For the first time, the TDHS-MIS 2021/2022 included data on early childhood development for children between the ages of 24 and 59 months. Survey findings suggest that only 47% of children in this age group are on track regarding milestones for the domains of health, learning and psychosocial well-being. Urban children fared better than rural children and girls better than boys (79).

In 2022 an estimated 1,700,000 adults and children were living with HIV in Tanzania. The prevalence of HIV in adults was 4.3. 1,600,000 of these (94%) were on antiretroviral therapy (81). In contrast only 48% of people living with tuberculosis had received full treatment in 2017 and 62% of children had received the second dose of measles immunization in 2021 (82).

Table 1 Selected health indicators for the population of Tanzania

Health indicator	**Result**	**Year**
Overall life expectancy	66 years	2021
Total fertility rate	4.8	2020-22
Maternal mortality ration	238/100,000 Live births	2020
Women with 4 or more antenatal care visits	65%	2020-22
Women delivering in health facilities	81%	2020-22
Women with postnatal care within 42 hours after childbirth	51%	2020-22
Under-five mortality	43	2020-22
Infant mortality	33	2020-22
Newborn mortality	24	2020-22
Children 24-59 months on track with development milestones	47%	2020-22
HIV-prevalence in adults	4.3	2022
Adults on antiretroviral therapy	94%	2022
People living with tuberculosis receiving complete treatment	48%	2017
Children receiving second measles vaccination according to recommended age	62%	2021

2.9 The health system and health service provision in Tanzania

Tanzania's health care system governance is decentralized with primary health care delivered in dispensaries, health centers (HC) and district hospitals (DH), while advanced care is provided in regional referral hospitals (RRH) and tertiary hospitals, such as zonal hospitals, and university hospitals. According to a World Bank assessment, private health facilities provided 22% of health care in 2013 (83). The Government of Tanzania (GoT) has introduced service agreements with these facilities, under a public-private-partnership, to ensure inclusion in planning, quality assurance and data provision. The number of health facilities in 2022 was 10,107 (Dispensaries 7,965, HC 1,466, Hospitals 676) according to census data (75). Health care provision in Tanzania is governed by the Ministry of Health (MoH), which is responsible for issuing policies, standards and guidelines, and by the President's Office for Regional Administration and Local Government (PO-RALG), in charge of primary health care provision (i.e. staffing, commodity planning and acquisition and financing for district hospitals, health centers and dispensaries) through Local Government Authorities. Facilities offering advanced care are overseen by the MoH.

Apart from the formal biomedical system, the population can also receive treatment from traditional healers, a profession recognized by the GoT. In contrast, traditional birth attendants are not officially recognized, and women are discouraged from delivering at home with or without assistance. Still, according to TDHS-MIS from 2015-16, a considerable proportion of women, especially from rural areas, chose to deliver at home (80), mostly with traditional birth attendants, but also with the help of female family members or friends (84). A study from Western Tanzania cited a low risk perception of men and women related to childbirth in general and men's lack of financial resources as the main reasons for giving birth at home (85).

Health system governance is centered around five-yearly planning cycles captured in Health Sector Strategic Plans (HSSP). The aim of the current HSSP V is to achieve Universal Health Coverage by 2030 and achieve the Sustainable Development Goals, with a focus on reproductive, maternal, newborn and adolescent health, communicable and non-communicable diseases and emergency preparedness (86).

According to HSSP V the lack of human resources for health is still substantial. Only approximately 50% of the positions needed countrywide were filled in 2021 (86). According to the available data, a majority of health care services are provided by women. Data from 2008 describes more female health care providers working in nursing and midwifery (86% female) and less working as non-physician clinicians (28%) or medical doctors (21%) (87). Data from 2020 on service availability and facility readiness showed that the number of doctors and nurse-midwives per 10,0000 population was 10.4, well below the numbers recommended by WHO (23/10,000) (88). There are three educational levels for nurse-midwives in Tanzania: i) A certificate level requiring two years of training,

ii) a diploma level with three years of training and iii) a master level based on a two-year training. So called non-physician clinicians (called clinical officers and assistant medical officers in Tanzania) have received a 5-year vocational training whilst medical doctors have attended university.

The general service availability index comprises of i) availability of standard precautions, ii) basic amenities, iii) basic equipment, iv) diagnostics and v) essential medicines. The index increased from 57% in 2017 to 69% in 2020. Despite availability of commodities, facility readiness for service provision, i.e. overall capacity to provide services, in terms of staff presence and availability of standards or guidelines, was lower than the general service availability index, e.g. reproductive, maternal, newborn, child and adolescent care, provision of antimalarial treatment and non-communicable diseases (88).

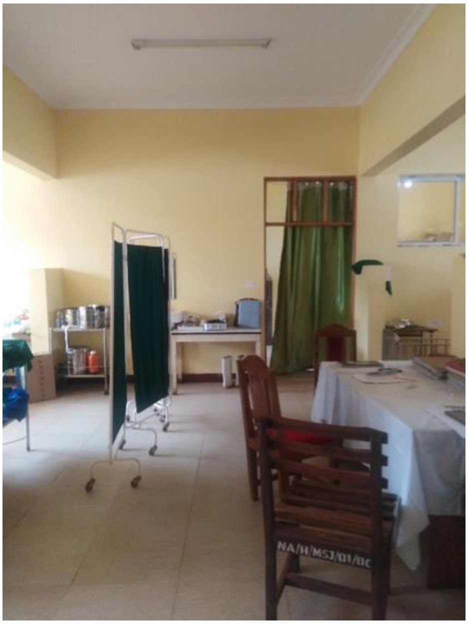


Figure 5 Impressions from a maternity ward in a typical rural district hospital

Health indicators displayed in table 1 above as well as low service readiness underline the importance of routine health data for commodity and human resource planning in Tanzania. In the HSSP V it is acknowledged that Information and Communication Technology (ICT) and digitalization have a pivotal role in realizing Universal Health Coverage and Sustainable Development Goals. The plan also stipulates the expansion of the use of capacity development measures related to the use of ICT to include in pre- and in-service training (86).

2.10 Routine health information management in Tanzania

The GoT has put an emphasis on HIS strengthening for over a decade (89). The DHIS-2 has gradually been introduced since 2010. The first National E-Health Strategy was published in 2013 and makes specific reference to DHIS-2 as the official digital HMIS (90). Tanzania was also one of the first countries in the region to produce a strategic investment roadmap to build a modern digitalized HIS (91) as well as a so-called enterprise architecture that operationalizes and describes how this system will be organized and which components it will comprise (89, 92). The current National Digital Health Strategy 2019-2024 explicitly links improved health outcomes and service quality to digitalization and data-driven decision-making (93). At the same time, the GoT recognizes persisting challenges with i) infrastructure, ii) funding, iii) user capacity, iv) power supply, v) lack of ICT experts and, vi) poor system interoperability and has acknowledged that these have led to increased workload for health care providers (93).

Routine health data is presently collected in three public concurrent systems, which are only partly inter-operational, i) the HMIS with its digital component DHIS-2, ii) *AfyaCare*, and iii) The Government of Tanzania Hospital Management Information System (GoT-HoMIS). The last two are electronic medical record systems.

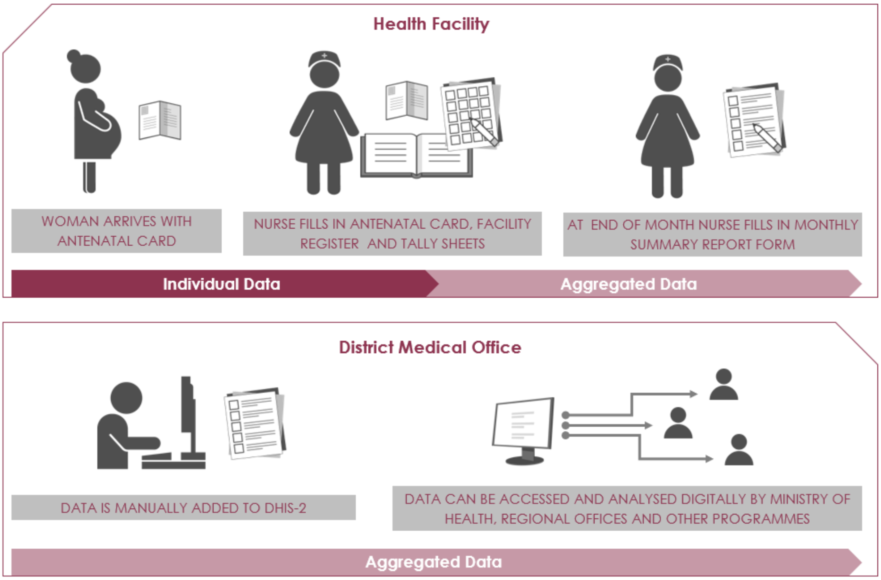


Figure 6 Data processing within the health management information system in Tanzania

While *AfyaCare* is used in regional referral hospitals, GoT-HoMIS has been rolled out to all district hospitals and the majority of health centers. Apart from these official systems, a plethora of vertical databases are in use, partly installed by donor organizations and with limited interoperability. Managers must therefore access several databases for synthesis.

2.11 Thesis framework

The focus of this research is on understanding the social dimensions and practices involved in conceptualization and implementation of health management information systems and its digitalization in Tanzania. I applied grand theories, implementation theories and a determinant framework (94) to inform the thesis study design, analysis, presentation of results and formulation of implications for policy, practice and research.

2.11.1 The non-adoption, abandonment, and challenges to scale-up, spread and sustainability framework (NASSS)

Complexity theory provides the basis for the *Non-adoption, Abandonment and Challenges to Scale-up, Spread and Sustainability of Technology-supported Change*

Efforts in Health and Social Care (NASSS) framework developed by Greenhalgh et al. According to Nilsen' taxonomy of theories in implementation science, the NASSS framework constitutes a determinant framework (94), describing the influence of system complexity on the introduction of health technology (95-97). Research has demonstrated how important contextual factors are for the institutionalization and scale-up of (digital) health technology projects (92, 98, 99) and how they may contribute to a failure in scale-up (99). The NASSS framework takes this into consideration and consists of seven domains that presumably influence successful incorporation or rejection of a new technology: (i) the condition, ii) technology, iii) value proposition, iv) individual adopters, v) organization, vi) wider system and vii) adaptation over time, (12). Each domain includes a list of factors that may pose complex challenges to technology implementation in the respective domain (Figure 7).

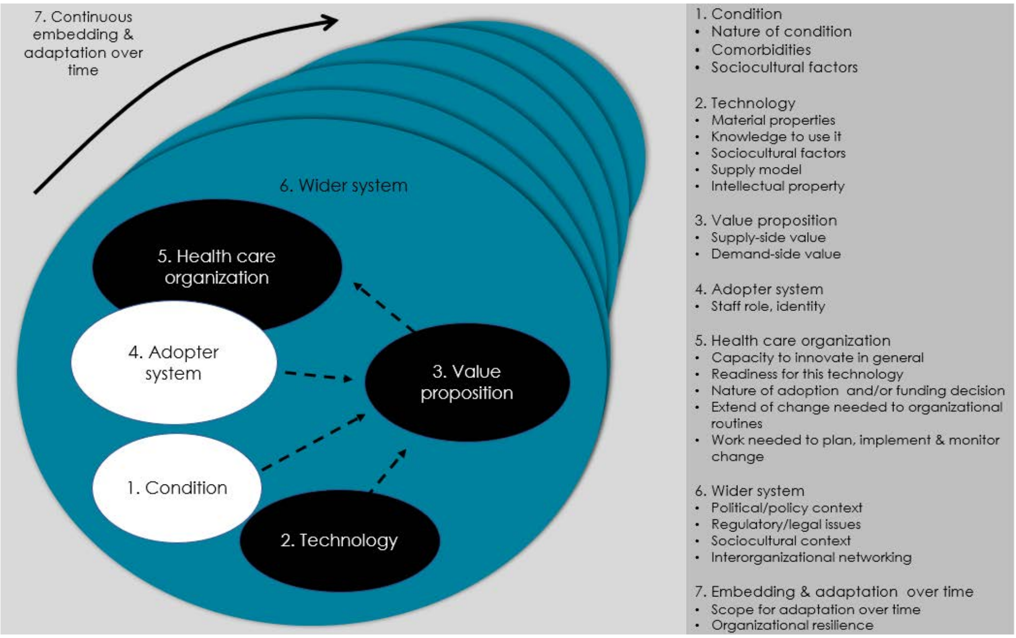


Figure 7 The NASSS framework reproduced from Greenhalgh et al 2019. Applied interdisciplinary theory in health informatics. Ed. Scott P. P 194, under CC-BY-NC-4.0.

A review of the literature on digitalization and health technology evaluations suggested that many projects introducing digital technology never make it from piloting to sustained implementation (92, 95). Greenhalgh et al. and other scholars postulate that this may be linked to the high degree of complexity at different system levels and suggest paying more attention to where complexity may prevent the introduction and institutionalization of a new technology (95, 99-101).

The NASSS framework integrates various social theories to uncover the complexity inherent in each domain, encouraging a discussion on how to reduce complexity before or during implementation. Greenhalgh et al. developed the NASSS framework based on their work on i) complex adaptive systems, ii) theories used for technology introduction and diffusion of innovation in organizational health technology introduction (95, 100, 102, 103) and ii) case studies using an ethnographic approach (95, 96). Since its inception, the framework has been applied in various health technology studies (99, 104).

According to the authors, the framework can be used during project design and planning, implementation and evaluation (95). While the overarching theory of the framework is complexity theory, the authors recommend the inclusion of other mid-level theories to understand and explain determinants for adoption or non-adoption in the seven domains (96). I found this integrative approach suitable for my aim to better understand social dimensions and practices related to the introduction and implementation of a specific technology within complex adaptive systems, like the health system in Tanzania.

2.12 Theoretical foundations

In this section, I describe the theories, models and frameworks I have used to underpin this thesis, acknowledging that there are many others that another researcher may have preferred.

Much of the literature on data, health information systems or data science is based on the paradigm of bioscience, using a positivist lens (102). Although this paradigm is in alignment with my professional career as a medical doctor, I realized that something was missing in relation to the meaning of data and what people make of it. I thought that identifying these missing realities might help answer questions about what it takes to make health management information systems perform well. I hypothesized that using a social science approach to data would assist me in answering my questions and add to the scientific literature on data, health management information systems and their digitalization.

To guide implementation science, Nilsen propagates the distinction between i) grand or classic theories, ii) implementation or mid-level theories, iii) determinant frameworks, iv) process models and v) evaluation frameworks (94). There is a plethora of grand and mid-level theories used to study digital health technology (102), e.g. actor-network theory (105), strong structuration theory (106) or the technology acceptance model (107). For my research, I made deliberate choices of the i) theories, ii) frameworks and iii) process models that from my point of view resonated most with the thesis aim.

2.12.1 Grand theories

Nilsen defines a theory as an explanatory concept that facilitates understanding of the relationship between defined variables. A grand or general theory is set at a level of abstraction that allows for almost "universal" application (94).

I chose social constructivism as one grand theory (94) as it prompts the researcher to look for a multitude of knowledge and meaning, which makes it applicable to a variety of settings (108, 109). I am referring here not only to how my participants constructed their knowledge about data and data systems, their working environment and digitalization but also to how my own perspective as a researcher was brought into my study design, methods, analysis and synthesis.

Social constructivism postulates that human beings seek to make sense of their interaction with each other, their life and work. Consequently, there is an abundance of subjective knowledge and interpretation rather than just one "reality" (108). The theory is thus linked to the construction of knowledge and meaning (108, 109). These two presumably play a role in the overall performance of health management information systems. Lee et al. and others argue that data collectors who know why they collect specific data often produce better quality than those with knowledge only of the procedures of data collection (110). Shared knowledge on the "why" is seen as an integral part of a positive information or data use culture (27, 70).

I also decided to apply another grand theory, complexity theory, which aligns well with my understanding of social constructivism as well as the nature of health care provision and its documentation systems in Tanzania (100, 111). In their study on six technology-based health care interventions, Greenhalgh et al. found that complexity was a common bottleneck to successful intervention implementation and that those interventions with multiple complexities were less likely to be institutionalized (99). Originating from the natural sciences, complexity theory has been found in various natural (112), artificial and social systems or networks, including health care systems (100, 101, 111, 113, 114). It has also been applied to the introduction of new health technology, including digitalization (99).

Complex adaptive systems (CAS) (101), like health care systems, are characterized by i) blurred borders, ii) interconnectedness of multiple actors, with a certain degree of freedom to act independently, iii) non-linearity and unpredictability, and iv) adaptation over time (100, 101, 113). Such systems are in need of different types of governance, planning and leadership as well communication and progress monitoring than a linear system comprising distinct components that deliver predictable outcomes (100, 115). Unpredictability may dictate an iterative approach to governance and leadership guided by so called "minimum specifications" that delineate "limits, direction, resources and permission" (111) instead of detailed plans. Leaders may need to identify what moves actors' behavior towards a common goal instead of labelling non-compliant staff as “refusing change” (111). In their evaluation of two hospitals in Kenya, Barassa et al. reported that, as compared to “*hard leadership*”, an approach that was flexible, inclusive and based on negotiation was perceived to lead to self-organization and resilience against underfunding (115).

2.12.2 Mid-level theories

Social constructivism and complexity theory both allow for the application or development of appropriate mid-level theories, something I deemed important given the complexity of the topic and the need for explanation at different levels of abstraction (94).

I decided to use the *Normalization Process Theory* (NPT) developed by May et al. (116) as a mid-level theory for Study I based on its description of the processes surrounding continuous sense-making, adoption and adaptation of new technologies at different actor levels, and the resulting perpetual self-organization (98). Plsek et al. acknowledge that NPT embraces and integrates the concept of system complexity (111). The theory describes the very social processes involved in introduction and institutionalization of innovation through individual and collective decisions and efforts (117). It is linked to individual and collective self-efficacy and seeks to illustrate the processes needed to incorporate innovation or technology into an existing workflow:” i) *Coherence*, ii) *cognitive participation*, iii) *collective action*, and iv) *reflexive monitoring*” (116, 118). Plsek at al. further acknowledge the complexity of these interactions and their context (98). NPT has been applied to health care technology introduction including digitalization (119, 120). The theory can serve to identify and document actors’ innovative attempts to incorporate technology in a complex system despite unpredictability and non-linearity. Such attempts commonly take place against a background of a set of tacit rules, which NPT might help identify.

Evidence suggests that the exertion of power by different actors is a critical determinant for the success of health care interventions (121), and that digitalization can also transform power relationships within the health care system in unintended ways (122). Erasmus and Gilson describe power relationships as an important and multilayered feature of health system structures, which is often overlooked during policy conceptualization and implementation (123). I opted to use Lipsky’s theory of street-level bureaucracy (124) to gain more understanding of power practices within Tanzania’s health system (124, 125). The theory describes the discretionary power practices enacted by lower-level managers and frontline workers when implementing policy (124). It illustrates how policies are sometimes transformed in unintended ways, leading in some instances to innovation (125-128). Most top-down approaches to power relationships are inspired by the theories of Weber (129). In the context of complex adaptive systems, however, where various actors shape each other's behavior while simultaneously being influenced by contextual issues (100), bottom-up power practices such as discretionary power may be more applicable. Complexity theory and complex adaptive systems' research describe a shift in power and power practices towards negotiation and permission as described by Barassa et al. (115) and Plsek et al. (111).

These power practices used in complex adaptive systems may also foster or prevent agency among different actors in contrast to less complex, linear production systems. Bandura defines self-efficacy and agency as an individual's perception of their personal ability to generate and modulate events or actions in their lives (130). He argues that an understanding of their knowledge and skills alone is insufficient when explaining why people do not act in an anticipated way despite them knowing what needs to be done. Rather, the concept of self-efficacy also includes continuous appraisal of one's own capability to perform an action in a given environment (130). Bandura links self-efficacy to collective efficacy and indirectly to social change. The importance of self-efficacy may therefore have been underrated in its importance in inducing positive changes towards a health system's information culture.

2.12.3 Process model

For Study I, I use the *Performance of Routine Health Information System Management* (PRISM) framework developed by Aqil et al. (70) as a process model based on its definition by Nilsen (94). The model helped me to better delineate the individual processes of the HMIS that I wanted to look at. A critical appraisal of its application in my research can be found under the section on methodological considerations.

The PRISM framework was developed to provide a model, and quantitative tools for a structured evaluation of routine health information systems, i.e. the HMIS, with the aim of improving its performance and monitoring any changes towards this aim (70). The model describes HMIS process determinants as inputs, influencing routine health information processes, which impact on outputs that influence the overall performance of the data system and consecutively the overall health system performance (Figure 8).

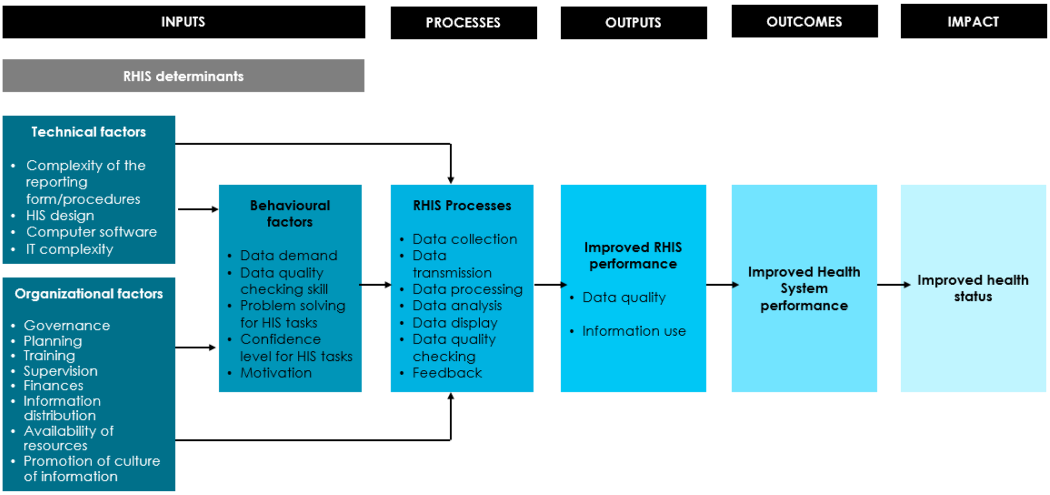


Figure 8 The performance of routine health information system management (PRISM) framework adapted from Aqil et al. 2009. Health policy and planning. 24. 217 - 228, under CC-NY-NC).

Arguably, the model is one of the first to include contextual factors as determinants for processes and eventually performance. According to the authors, this demonstrates a paradigm shift in relation to the perception of routine health information systems (70).

2.13 Thesis rationale

Research suggests that data and statistical procedures are social constructs embedded in a society's discourse. There is evidence that contextual factors, including socio-cultural norms, influence the performance of health and health information systems. Nevertheless, there is paucity of information about how aspects of governance and implementation of data processes including digitalization in settings like Tanzania are influenced by social norms and processes.

Research has outlined what may be needed to improve HMIS data quality and use. The measures that have been recommended are mainly located at the individual level of health care providers and managers or at technology level and often focus on capacities rather than interaction between actors within organizations. This neglects the social fabric that forms organizational culture. It is unclear how sociocultural practices might impact existing explicit or tacit organizational norms, that foster or hinder a change in individual and organizational behavior towards "a culture of data quality and use".

Information or data use culture has been suggested as important to guide improvements in data quality, its' use and health information system performance. However, there is a paucity of knowledge on the mechanisms underpinning prevailing organizational and social cultures around health information systems and how these can be re-directed to improve system performance.

Although social scientists increasingly describe the social dimensions of data and data systems, there is a knowledge gap on how sociocultural practices impact digitalization of health management information systems. There is therefore little evidence on how the introduction of digital technology is shaped by adaptation and what role these sociocultural practices could play in this process.

3 Aim and research questions

Aim: To understand the social practices involved in generating and processing routine maternal and newborn health data using paper-based and digital tools within the health management information systems in Tanzania.

This aim led to the following **research questions** for the four studies contributing to this thesis:

- How do health care providers and healthcare managers perceive Smart Paper Technology and the current health management information system in terms of acceptability, usability and feasibility; how much time do health care providers spend on documentation with the new system; how did health care providers and healthcare managers engage with the new technology (Study I)
- What is the level of data quality from Smart Paper Technology for maternal care services in terms of i) completeness and timeliness and ii) internal consistency? (Study II)
- What are the processes involved in health care providers' data use; which type of information is used together with health management information system data and for what purposes? (Study III)
- How do health care policymakers perceive and experience working with data, data systems and the introduction of digital technology related to the governance of health management information systems? (Study IV)

4 Methods

The methodology of this thesis is grounded in social constructivism and complexity theory. The thesis framework has been adapted from the non-adoption, abandonment and challenges to scale-up, spread and sustainability of technology-supported change efforts in health and social care (NASSS) framework (96). Figure 9 below illustrates the domains each of the four studies comprising this thesis focus on.

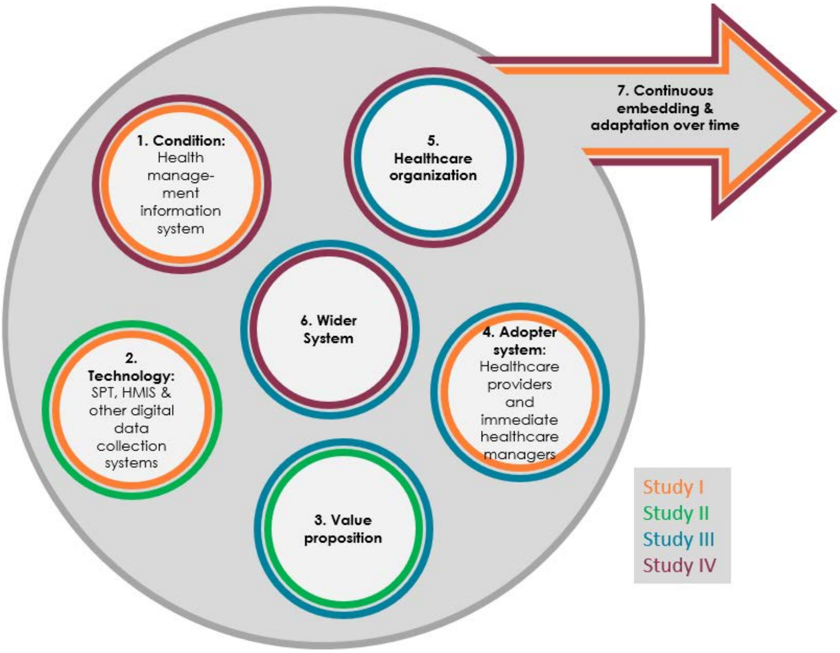


Figure 9 Thesis framework adapted from Greenhalgh et al. 2019. Applied interdisciplinary theory in health informatics. Ed. Scott P. P 194, under CC-BY-NC-4.0.

4.1 Setting

All four studies were conducted in Southern Tanzania, at different but geographically close sites, because they were embedded in two different implementation science projects.

Tanzania's Southern Zone comprises of two regions, Lindi and Mtwara, and is a mostly rural area, at times difficult to access (Figure 10). Large parts of Lindi region, for example, cover the Selous Nature Reserve, mostly inaccessible during the rainy season between March and May. In the past ten years construction of tarmacked roads has partly alleviated this problem, but many health facilities still lack easy access during heavy rainfall that this part of Tanzania experiences.

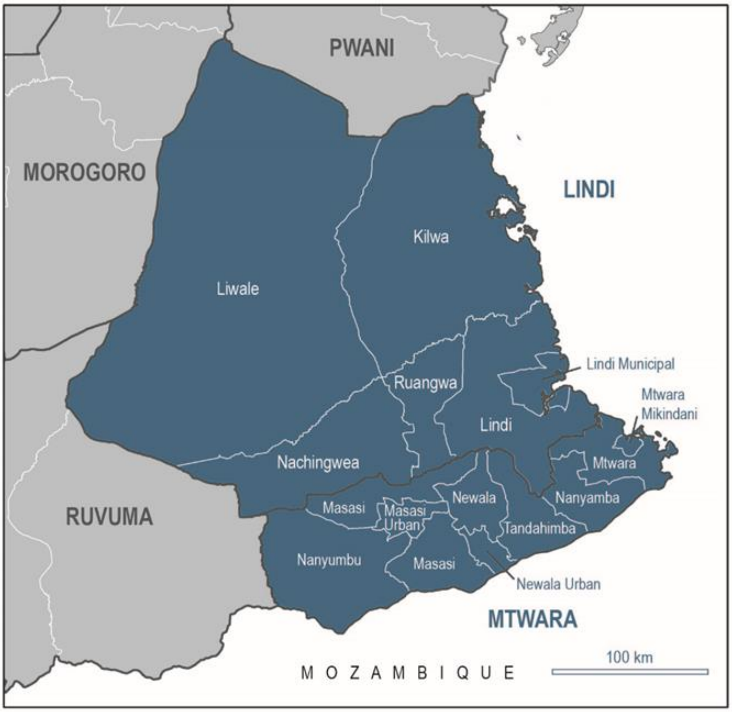


Figure 10 Map of the southern zone of Tanzania

The two regions together have a population of 2,828,975 inhabitants, thereby belonging to the less densely populated regions of Tanzania mainland (75). While the coastal parts of the Southern Zone are mainly influenced by coastal Swahili culture, the hinterland is predominantly inhabited by the matrilinear ethnic groups of Yao, Ngoni, Mwera, Makua and Makonde. Most of these still speak their own language but are also fluent in Kiswahili, the national language of Tanzania (131). Matrilineality did not necessarily translate to more empowerment for women in the Southern Zone: TDHS-MIS 2015-16 reports that only 61 % of female respondents claimed to make decisions on their own health as opposed to 72% for mainland Tanzania (132).

Inhabitants of the districts included in this thesis are mainly subsistence farmers, cultivating cash crops like cashew nuts, ground nuts, beans or maize. Especially cashew farming is extensively practiced in several districts of the Southern Zone and has led to the substantial economic wealth of individuals while much of the population still lives in poverty (74).

4.1.1 Health care and its documentation in the Southern Zone of Tanzania

In 2022 the two regions of the Southern Zone had 33 hospitals, 72 health centers and 510 dispensaries, the vast majority being public health facilities (75).

Maternity services in the included facilities are provided by nurse-midwives and non-physician clinicians. The district hospital and some of the health centers employ medical officers. Where patients needed a referral for specialist services, they had to travel 50-100 km to one of the two referral hospitals.

As described in the background section, nurse-midwives are mainly responsible for the collection of routine health information. At the time of the research GoT-HoMIS was functional in most administrative and outpatient departments of hospitals, but maternity wards were not yet connected to the system. HMIS data was collected in paper-based maternity registers and later digitized into DHIS-2 by departmental nurses in-charge at hospital level and in most health centers, and by the district HMIS focal persons and other district managers for dispensaries. The private referral hospital included in Study III employed a locally developed electronic medical record system with no interfaces to GoT-HoMIS or DHIS-2. However, paper-based registers and other documentation sources were still maintained to mitigate hardware or power failure.

4.2 Participants

Participants of the four studies were health care providers and managers at sub-national and national level, who were engaged with data or data systems processing routine health data (Table 2). Health care providers working in included facilities and their managers at facility and district-level often originated from the respective or neighboring districts or had lived in the area for many years. There was minimal influx from other regions of Tanzania. As such, they live closely with the population and had some insights into local culture and norms.

Study I was conducted in one public district hospital, one public health center and one public dispensary and Study II in the same facilities, with one health center and nine dispensaries added (all public) from the same district. Study III was carried out in one private-not-for-profit referral hospital and one public district hospital. For Study IV, health care managers from two district councils and two regional health management teams in Southern Zone were interviewed, together with health care managers from national level.

Study I and II were a part of the ONGEZA project, implemented in a remote, rural district in Southern Tanzania. Study III and IV were conducted under the ALERT project in three neighboring districts in Southern Tanzania. In addition, for study IV I interviewed participants from the national level in Dodoma, the capital of Tanzania.

Table 2 Participants per study

Study	Host project	Study sites	Participants	No. of participants
I	ONGEZA	1 Hospital, 1 Health Center, 1 Dispensary	• Maternity care providers • District health managers	18 (FGD) 6 (IDI)
II	ONGEZA	1 Hospital 2 Health Centers, 10 Dispensaries	N/A	N/A
III	ALERT	2 Hospitals	Maternity care providers	14 (IDI) 11 (FGD)
IV	ALERT	• Council/Regional Medical Offices, • Ministry of Health • PORALG	• Regional and district health managers • National health managers	8 8

4.3 The ONGEZA Project

This research project was implemented in 30 out of 46 health facilities providing maternity care in one District Council between 2019 and 2020 under a research cooperation between Ifakara Health Institute (IHI), Dar es Salaam, Tanzania, Karolinska Institutet and the SHIFO foundation, Stockholm, Sweden. The project aimed to pilot and evaluate an innovative semi-digital technology, *Smart Paper Technology* (SPT) supporting the DHIS-2 through automatization of previously manual data processing steps (Figure 11). The district was chosen as the research site for the ONGEZA project based on a previous research project conducted by IHI on quality improvement, which included health care providers in two district councils generating, analyzing and using data from plan-do-check-act cycles (133).

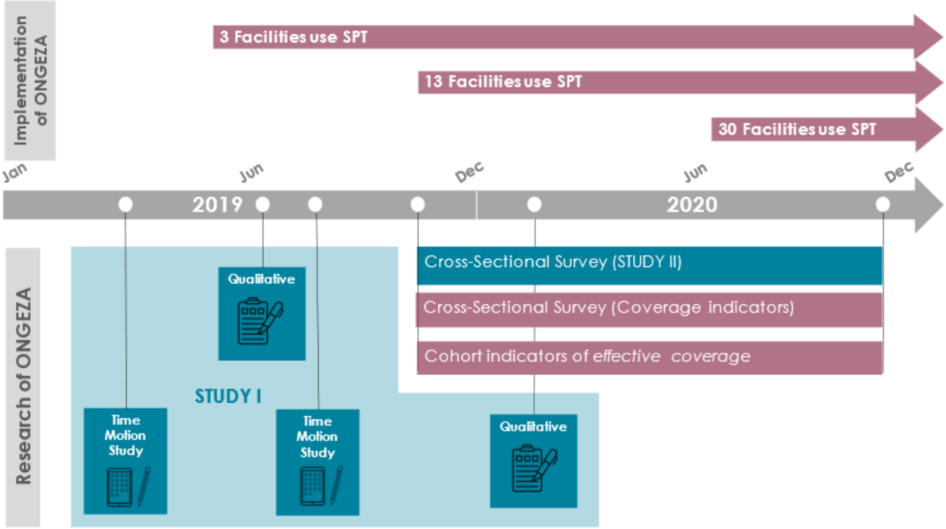


Figure 11 The ONGEZA project (Study I and II data collection highlighted in petrol, other research under ONGEZA and implementation activities highlighted in plum).

4.3.1 Smart Paper Technology

SPT was initially developed by the SHIFO foundation in 2016 to improve routine data processing for vaccination services in Northern Uganda, with the aim of replacing the paper-based local health information management system (134). For the ONGEZA project, the technology was adapted for data collection in maternal health services (Figure 12).

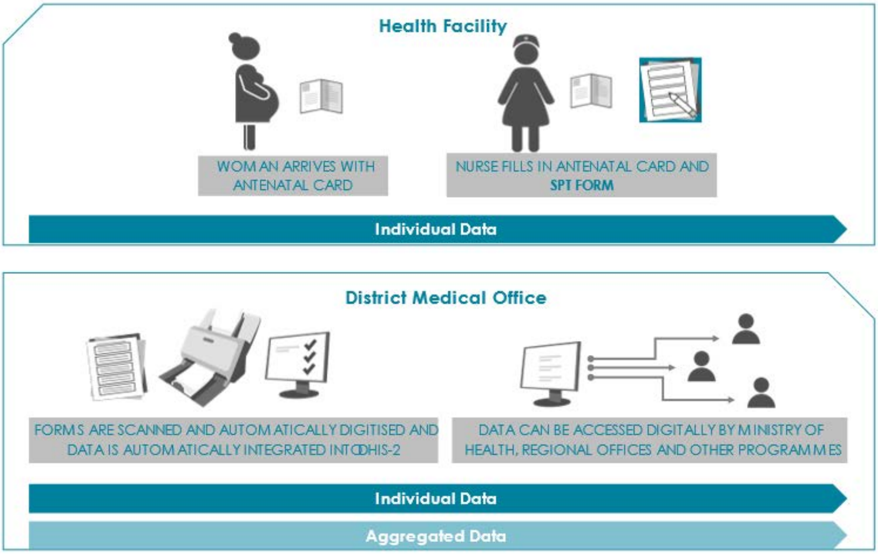


Figure 12 Data processing with smart paper technology

Forms are scanned through a bar code at the bottom using a non-specific scanner-copying machine and content is digitized by a special software, which exports data to the system's secured server. A digital dashboard displays individual patient data and aggregated coverage data in electronic client register and monthly summary reports. Interfaces with other data systems, especially with DHIS-2 can be constructed (Figure 13).

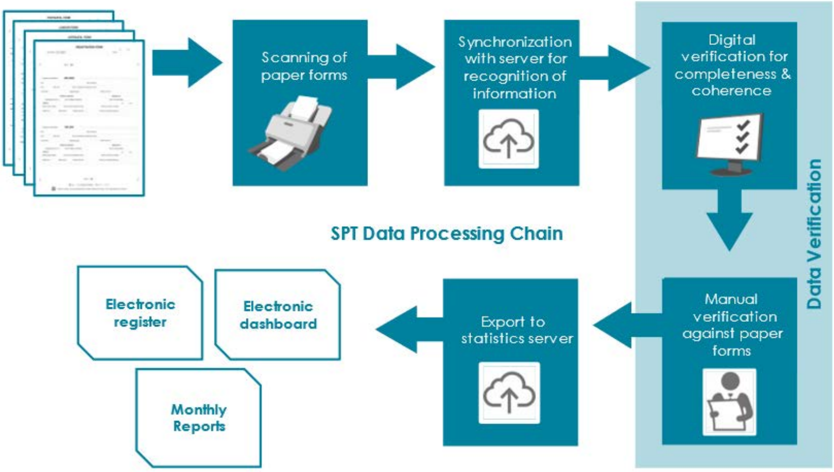


Figure 13 Processing of smart paper forms

According to SHIFO foundation's previous experiences, SPT has several **advantages** over the partially paper-based data collection and processing system applied to HMIS in Tanzania (Figure 2) (135): i) A single form, where information is mostly ticked in boxes instead of spelled out, replaces facility register books, ii) digitization of data is automated through software instead of manual data entry, iii) the software flags the most prominent inconsistencies during verification, which is done on the spot during digitization, with opportunities for immediate follow-up and iv) the dashboard displays individual client data in an electronic facility register and aggregate data. At this point remaining inconsistencies or implausible data can be verified electronically within the primary disaggregated data set instead of verification officers travelling to facilities (Figure 13). These, together with positive results from other evaluations of SPT for vaccination services in Uganda and The Gambia (136, 137), made a compelling argument to use and evaluate SPT for clinical services such as maternal and newborn health services.

4.4 The ALERT Project

The *Action Leveraging Evidence to Reduce Perinatal Mortality and Morbidity in sub-Saharan Africa* (ALERT) research project runs from 2020 to 2025 in 16 hospitals in Benin, Malawi, Tanzania and Uganda and aims to develop and evaluate an intervention to improve intrapartum care in those hospitals. Karolinska Institutet is the principal investigator of a multi-national consortium of eight academic institutions in seven countries (138). In Tanzania, the ALERT project is conducted by *Muhimbili University of Health and Allied Sciences* (MUHAS) and the *Aga Khan University* (AKU), Dar es Salaam.

The project's design takes a health system perspective and includes aspects of governance, quality improvement, capacity building or midwives, spread over nine different work packages. ALERT includes a co-design and formative research phase followed by an implementation phase with continued co-creation. The intervention, consisting of continuous quality improvement, formal training, mentoring and stakeholder engagement, is evaluated using a i) stepped-wedge trial, ii) realist process evaluation and iii) economic evaluation (138).

Primary outcomes of the evaluation are facility-based early perinatal mortality and fresh stillbirth rate. These are measured using an electronic registry, specifically designed for the project, collecting peripartum routine health data based on the DHIS-2, together with clinical data from women during labour and childbirth who delivered at least one baby of at least 1,000 g (138).

The four ALERT research sites in Tanzania were chosen based on their number of deliveries and caesarean sections as well on their remoteness in a rural setting (138). The two hospitals for the project's formative research were chosen based on a heterogeneity assessment carried out by the ALERT Tanzania team from MUHAS in which I was included. The aim of this assessment was to select two hospitals which represented typical private and public hospitals in rural Tanzania and for logistic reasons to keep data collection and analysis efficient.

Study III was embedded in the formative qualitative data collection of the project's work on responsiveness and professionalism (Figure 14).

Study IV followed up on results from a quantitative hospital assessment and a desk review of national policy elements pertaining to facility readiness, leadership and governance conducted under the ALERT project (138, 139) to gain further knowledge about Tanzania's efforts to improve data quality and use and to implement digitalization (Figure 14).

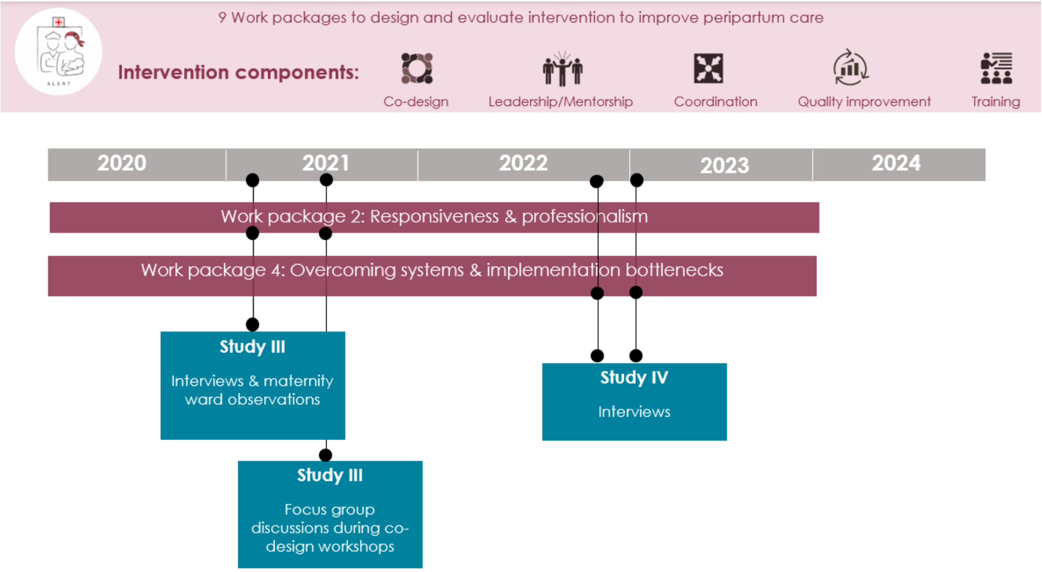


Figure 14 The ALERT project. Study III and IV data collection highlighted in petrol, ALERT work packages the two studies contributed to highlighted in plum.

4.5 An iterative approach to methodology, data and data systems

I set out to examine the evaluation and implementation of digitalization projects to support routine health data collection and processing. However, my experiences and the results from Study I and II left me wondering how different actors within health data systems would understand, produce and use data, and how these would influence the conceptualization and management of such a system. Study I and II findings and the application of social constructivism prompted me to reflect on how a system that acknowledges the broadest possible range of actors' "realities" regarding data and data systems could look like and how digitalization might assist this endeavor. Study IV contributed knowledge to underpin this reflection.

4.6 Methodology used for each study

A mix of quantitative and qualitative methods was applied for this research to capture processes around routine health data collection and digitalization. This provided an opportunity to better understand the methods' advantages and bottlenecks, how the different methods interact with each other and how they can be used for triangulation of results (Table 3).

In this section I will report the methodologies used for each study and critically evaluate the rationale for their application. An assessment of the overall study methodology is provided in the section on methodological considerations.

Table 3 provides an overview of the design and methods used for the four Individual studies.

Table 3 Overview of the designs and methods used per Individual study

Study	Main objective	Study design and methods	Study population	Sampling	Analytic methods
Study I Feasibility, usability and acceptability of a novel digital hybrid-system for reporting of routine maternal health information in Southern Tanzania: A mixed-methods study	To evaluate how health care providers and health care managers perceive *Smart Paper Technology* and the current health management information system in terms of acceptability, usability and feasibility and how much time do health care providers spend on documentation with the new system.	Convergent parallel mixed-methods design with: 1. Quantitative time-motion study. 2. Qualitative study using focus group discussions and in-depth interviews.	1. HCPs performing tasks in health service provision in ANC, labour care and PNC in three health facilities as defined by a task list. 2. Maternity care providers working in ANC, labour care or PNC and involved in routine health data processing in three health facilities. 3. Health care managers at district level engaged with routine health data processing or use.	1. Sample size calculation of 240 hours of observation before and after SPT introduction based on literature and inflated by factor 1.5 to account for cluster effects, with 80% power at 5% significance level to detect changes in time spent on documentation. 2. Purposive sampling.	1. Difference in proportion of time spent pre- and post-intervention using Fisher exact test and multivariable models. 2. Reflexive thematic analysis using Normalization Process Theory.
Study II Caught in the data quality trap: A case study from the evaluation of a new digital technology supporting routine health data collection in Southern Tanzania	To assess the level of data quality from *Smart Paper Technology* for maternal care services in terms of i) completeness and timeliness and ii) internal consistency	Cross-sectional study using quality dimensions, metrics and indicators adapted from the WHO Data Review Toolkit.	Routine health data collected during ANC, labour care and PNC in 13 health facilities.	13 health facilities in one district purposely sampled to include facilities with use of SPT for at least one year. Due to small sample no sample size or statistical power calculation undertaken.	Comparison of descriptive statistics on coverage indicators per facility, such as ratios and frequencies between SPT and two data sets from DHIS-2 (2018-2019 and 2019-2020)
Study III Understanding maternity care	To improve understanding about the processes involved in health care providers’	Ethnography using 1. In-depth interviews, 2. Focus group discussions and 3.	1. Maternity care providers engaged in health service provision and routine	1. Purposive sampling for IDIs and observation	Constructivist grounded theory

Study	Main objective	Study design and methods	Study population	Sampling	Analytic methods
providers' use of data in Southern Tanzania	data use; which type of information is used together with health management information system data and for what purposes	Non-participatory observations.	health data processing in two hospitals. 2. Maternity care providers engaged in health service provision and routine health data processing in two hospitals.	2. Theoretical sampling for FGDs 3. Convenience sampling (all maternity care providers on shift during observation).	
Study IV "Implementing a policy is something else". A case study on data culture and governance of complex health information systems in Tanzania	To understand how health care policymakers perceive and experience working with data, data systems and the introduction of digital technology related to the governance of health management information systems	Qualitative study using in-depth interviews	1. Health care managers engaged in development and/or use of routine health databases at national level. 2. Health care managers engaged in development and/or use of routine health databases at subnational level.	Purposive sampling	Reflexive thematic analysis using Street Level Bureaucracy Theory

HCP= Health Care Provider, ANC= Antenatal care, PNC= Postnatal care, SPT= Smart paper technology,, WHO= World Health Organization, DHIS-2= District Health Information System-2, FGD= Focus Group Discussion, IDI= In-depth Interview

4.6.1 Study I

Aim

The aim of study I was to evaluate how health care providers and health care managers perceive Smart Paper Technology and the current health management information system in terms of acceptability, usability and feasibility and how much time do health care providers spend on documentation with the new system.

Design

A mixed methods approach is seen by many as the most suitable approach for the evaluation of complex interventions (140) including health information technology (92, 141, 142). We used a convergent parallel mixed-methods design as described by Creswell and Plano Clark Figure 15 Study I convergent parallel mixed-methods design: Qualitative and quantitative data was collected concurrently, analyzed first separately and then in an integrative manner (143).

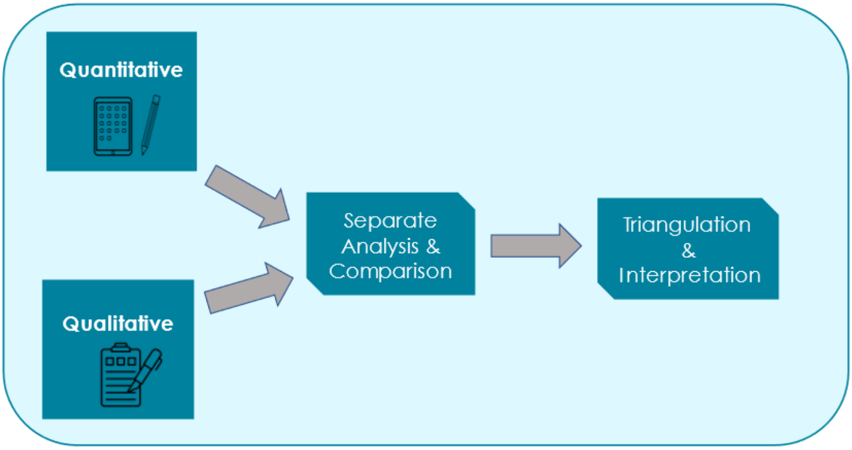


Figure 15 Convergent parallel mixed-methods design used for study I

This type of mixed-methods design was chosen because of the need for triangulation to contextualize the implementation of a new technology. Since there was no prior experience with applying SPT to clinical services, we used this design, where qualitative and quantitative data is collected concurrently, to adjust SPT forms and support maternity care providers in integration of the technology in routine workflow.

A time-motion study (TMS) (144-147) was conducted for the quantitative strand to assess time spent on documentation before and after the introduction of SPT, in three health facilities at all primary health care levels. The aim was to evaluate the impact of SPT introduction on documentation and patient care in ANC, labour care and PNC. TMS has been increasingly applied to the introduction of digital health technology, mainly on electronic patient records, in different settings (144, 148) including those similar to Tanzania (146), and for SPT (137).

The methodological design described by Pizziferi et al. (144) and Zheng et al. (145) was used to conceptualize the TMS for Study I. A task list for ANC, labour care and PNC was designed in cooperation with the reproductive and district child health coordinator and hospital staff. It is comprised of 141 tasks grouped in three categories (documentation, direct patient care and other tasks) and 10 sub-categories. After digitalization into ODK software, the list was translated into Kiswahili, pre-tested and refined during practice observations, as part of a five-day training for data collectors.

For the qualitative strand we carried out eight focus group discussions (FGD) with maternity care providers who collected data for the SPT system, and the official paper based HMIS in the three health facilities. We also conducted 11 in-depth interviews (IDI) with health care managers from the council health management team in the study district. This strand was informed by NPT (116) and used the PRISM framework as a process model (70).

Both PRISM and NPT, together with the researchers' own experience with health care delivery and its documentation in Tanzania, informed the development of the topic guides. The topic guides for the second qualitative data collection in February 2020 were informed by the first data collection.

Study population

The study population for the quantitative strand were health care providers working in ANC, labour care or PNC in the three research facilities during the two periods of data collection. The study population for the qualitative strand comprised of i) health care providers working in ANC, labour care or PNC and engaged in the use of SPT and HMIS documentation in the three research sites and of ii) health care managers engaging with SPT and involved in data processing for DHIS-2 at district level in the research district.

Sampling, sample size calculation and recruitment

The three health facilities chosen for Study I were determined by their enrollment in SPT training as pilot sites, chosen by the council health management team. This choice was informed by patient and delivery numbers, the goal to include all health care levels in the piloting and physical accessibility.

A sample size calculation was performed to detect a difference in time before and after SPT introduction, spent on documentation as a proportion of time spent on overall patient care related tasks (80% power at 5% significance). Baseline (25% of time spent on documentation) and post-SPT-introduction (18% of time spent) estimates were drawn from a previous publication using SPT for vaccination services in Uganda (137). We increased the result (160 hours at a two-sided p value of 0.45) by factor 1.5 to accommodate clustering since the same group of health care providers per facility were re-visited. This resulted in 240 hours of task observation needed before and after SPT introduction each. All health care providers working on a given day of observation were eligible to be included.

Sampling for the qualitative strand used a purposive approach to include health care providers and managers with good experience in HMIS and SPT data collection and processing. Monitoring of saturation was based on information power as described by Malterud et al. (149). This concept proposes that the richer in information a group of participants is, pertaining to the topic in question, the smaller the sample size needed to reach redundancy. The authors propose five determinants for information power: i) study aim, ii) how closely the sample relates to the aim, iii) choice of underpinning theory, iv) quality of researcher-participant rapport and v) analytic strategy. Our research aim and objectives narrowed an already specific topic, the adoption of SPT within documentation tasks for HMIS, down further. FGD and IDI participants consisted mainly of nurse-midwives and clinicians whose daily task was to process routine health data, and who were all trained and mentored for SPT use. Since most managers had previously worked clinically, they were also knowledgeable of data processes. Data was collected by an experienced qualitative researcher and me, who were known to many participants from previous research or implementation work and rapport was perceived as well established. Although our participants held similar knowledge related to the two very specific systems, the way they adopted SPT at their respective health care level may have differed. Since these aspects were important for this study, the sample included participants from all levels of primary health care. Based on this, together with the fulfillment of the other four components of information power and the use of thematic analysis where saturation is seen as determined by the standpoint of the researcher (150), our sample yielded information rich and detailed enough to meet the study aim and respective objectives. None of the potential participants who were approached refused to be interviewed or recorded.

Data collection

Data for the quantitative strand was collected before (February and March 2019) and after (August 2019) the SPT training for the three facilities (Figure 11). Data collectors for the first data collection were researchers experienced in observations and quantitative data collection who regularly cooperated with IHI in research projects. They received a five-day training, developed and facilitated by the ONGEZA project team that included i) an introduction to TMS methodology, ii) ethical aspects of non-participatory observation, iii) a review of the task list, iv) familiarization with digital equipment, v) supervised test observations in other health facilities, iv) Task list review and feedback from observations with adjustment of the task list and vi) unsupervised observations with feedback. The training concept followed the description of Zheng et al. (145). Data collectors for the second data collection in August were recruited among health care providers from the research district since the first group was not available at this time. The second group of observers received the same training, facilitated by the same team.

Health care providers were shadowed for 13 days from the beginning to the end of their shift, after consent. Their tasks were recorded in the electronic survey tool. Morning and afternoon shifts during weekdays and weekends were observed. The reason for nightshifts not being observed was that the research team feared that services might be compromised by the presence of observers because of the lower number of staff present and the nature of cases, which often present as emergencies.

Data for the qualitative strand was collected in July 2019 by the same researchers as previously, shortly after the June introduction of SPT, and in February 2020, after facilities had worked with SPT for eight months (Figure 11). IDIs and FGDs were held in Kiswahili and were recorded after consent. Initial open and general conversation and questions helped to establish rapport and a relaxed atmosphere during IDIs and FGDs. Participants were generally open to discussing a wide range of topics and during the second round of data collection, more sensitive issues such as alteration of HMIS books were raised.

Analysis

For the quantitative strand, descriptive statistics were generated using Fisher Exact test to examine length and number of observed shifts before and after SPT introduction, by level of care, department, cadre and years of experience. We then generated a bivariate model to calculate the probability of a true difference between pre- and post-SPT introduction for task categories and sub-categories using proportions and confidence intervals, expressed as odds ratios for statistically significant values. Finally, a multivariable model was developed that included task categories and subcategories adjusted for the above confounders to calculate probability expressed as odds ratios and with statistical significance after adjustment.

Reflexive thematic analysis (TA) was used. Reflexive TA seeks to identify clusters of meaning that guide a reflexive process of familiarization, coding, development, and refinement of themes (151-153). The flexibility of the method postulated by Braun and Clarke with regard to the use of theory and the use of inductive and deductive coding, made it particularly suitable for this data analysis. Although several social and behavioral theories exist regarding the interaction between humans and health care technology or technology in general, as well as on human sense-making of innovation, we wanted our analysis to be primarily data-driven and embedded in a theory-informed conceptual framework (152).

Initially, coding was applied to the English translation of Kiswahili transcripts but a loss in nuance and meaning was noted when compared to the Kiswahili version. Since the team consisted of Kiswahili speakers, we decided to code on the original transcripts. Coding was done inductively for four data sets by a senior qualitative researcher from IHI and myself. We then met to discuss clusters of codes that shared meaning, which we grouped together applying our framework at category-level. I then continued applying these codes to the entire data set, whilst adding new codes and clusters that I identified. Regular reflexive feedback sessions were held with one of my supervisors, where initial themes were developed further, and new code clusters were discussed.

4.6.2 Study II

Aim

To assess the level of data quality from Smart Paper Technology for maternal care services in terms of i) completeness and timeliness and ii) internal consistency

Design

A cross-sectional survey design was used over 12 months in 13 health facilities, comparing SPT data quality with the currently used DHIS2, based on WHO's Data Quality Review (DQR) Toolkit (39, 40, 154). This data quality assessment tool was originally designed to monitor HMIS data quality, mainly at subnational and national level, but has been applied to DQR at district level in several studies in Tanzania (30) and other, similar settings (29, 155) including SPT for vaccination services in The Gambia (136). The toolkit proposes a set of specific health care indicators, including those for maternal and child health services, based on four data quality dimensions and further broken down into metrics and indicators for each dimension. Data quality dimensions include i) data completeness and timeliness, ii) internal consistency, iii) external consistency compared to other databases and iv) external consistency compared to population data.

Initially the ONGEZA team had envisioned monitoring a set of key performance indicators, specifically developed for SPT in maternal and newborn care, but district health authorities expressed their interest in monitoring indicators commonly used for their reporting to national level, i.e. those which were included in DHIS-2. In addition, definitions and use of data quality dimensions, their indicators and assessment methods varied in the literature, thus reducing comparability of potential findings for scale-up decisions (156). The fact that several studies described the use of WHO's DQR toolkit made a compelling case for its use in this study (29, 30, 136).

For Study II we used two of the four quality dimensions, i) completeness and timeliness and ii) internal consistency (39). It was not possible to assess external consistency through comparison with other databases or population data because i) available external databases, e.g. from antenatal care or HIV care and treatment services, were all based on HMIS/DHIS data for maternity care indicators. Furthermore, data from the last population-based survey, the TDHS-MIS was from 2016 and thus outdated. To date, results from the most recent TDHS in 2022 have only partly been released (59). In addition, our sample size is too small for a comparison with population-based data which is usually reported at regional level (39, 40).

I adapted indicators for this study from applicable indicators from the DQR tool kit and added six more: i) Four indicators reflecting specific features of the SPT system, not included in the DQR tool kit, e.g. timeliness of SPT form submission, and ii) two indicators using individual data, which could only be generated by the SPT system (see table 2 in Article II).

Study population

Study II used data routinely collected during health care for pregnant, delivering or postpartum women visiting ANC, labour care and PNC in the 13 facilities included.

Sampling

The 13 health facilities were selected from all 30 health care facilities with maternity care services in the district where SPT had been rolled out between June 2019 and July 2020 (Figure 11). The rationale for this choice was that by the end of the overall project in December 2020, these facilities would have used SPT for at least 12 months. The hospital, one health center and one dispensary had served as pilot sites. The remaining nine dispensaries and one health center from the study sample were trained on SPT use in November 2019. Due to the low number included, sample size and power calculations were not performed.

Data collection

Health care providers were required to complete a SPT registration form for each woman newly attending one of the three services. The unique identifier would then be used for subsequent visits across all three service areas. Health care providers completed one form for each service encounter of individual women together with the respective HMIS register book and the woman's ANC card (Figure 12). At least once a month, or whenever a health care provider or officer in charge of the included facilities went to the district capital, they brought SPT forms collected in the facility to the scanning station at the district hospital. A scanning officer, employed by the project, scanned the forms and a data verification officer, initially employed by the project, and later a trained health care manager from the district health team, conducted data verification digitally and manually.

Study II is based on routine health data from SPT and DHIS-2 between November 2019 - October 2020. We added DHIS-2 data from November 2018 - October 2019 to create data trends for coverage indicators over a longer period of time (39) as stipulated by the WHO toolkit and to triangulate data based on the available literature on levels of DHIS-2 data completeness and consistency in Tanzania and similar settings (29, 30).

Analysis

Data was downloaded from both databases in January 2021 and, supported by one of my supervisors, I generated descriptive statistics, such as frequencies and ratios using STATA 16 (Stata Corp LLC, Texas, USA). Indicators from the three data sets were then compared and differences were described as described by the WHO toolkit.

4.6.3 Study III

The design and methodology of this study were strongly influenced by results from Study I and my experiences during data collection and analysis. I had learned that my participants at facility level were unable to describe the data they used and how they used it. These findings informed the design and topic guides for Study III.

Aim

To improve understanding about the processes involved in health care providers' data use; which type of information is used together with health management information system data and for what purposes.

Design

I chose an ethnographic and co-design approach based on constructivist grounded theory as described by Charmaz (157, 158). To make use of triangulation, we included IDIs, observations and FGDs conducted as part of the ALERT co-design process. Most of the literature around routine health data processing uses quantitative methods, with only few studies applying qualitative methods (5, 42, 58, 59, 68). Greenhalgh et al. recommend the use of ethnographic methods for the study of digital technology in complex systems such as health care settings (103) based on the observation that most literature on the implementation of digital technology is grounded in a positivist paradigm which fails to describe the processes and perceptions associated to its use. Co-design empowers participants to delve into topics that are relevant to them at more depth (159). By using this approach, together with theoretical sampling for the FGDs, we aimed to obtain a deeper understanding of participants' motivation and sense-making related to data and data use.

Other studies' qualitative results and findings from Study I show that health care providers often feel disempowered to use the data they collect. Still, I could not find information about what meaning these "data collectors without agency", as I call them, ascribed to the data itself, the processes of their documentation, and what other data they would rather have used and for what purpose (42, 58, 59). I also failed to grasp how the maternity ward working environment in the research sites contributed to maternity providers' sense-making of data collection processes their data use. I felt that there may be an opportunity to develop theory around these issues as described by Charmaz for grounded theory (158).

Study population

Maternity care providers working in the labour ward of the two included hospitals were chosen as the study population for this study.

Sampling and recruitment

Sampling for in-depth interviews was purposive, including all maternity care providers engaging in routine health collection processes. This strategy allowed for maximum variation, since different health cadres, age and sex were included, as far as they reflected the composition of the Tanzanian health workforce. In the end, 14 of the 18 in-depth interviews with maternity care providers collected under ALERT were used for Study III. Four interviews did not contain information about data use and perceptions on data since the interviewers had shifted their focus towards other topics within the ALERT topic guide. The remaining 14 participants talked in-depth about their views on data, which type of data they would use and for which purposes. None of the potential participants approached refused to be interviewed and all gave their permission to be recorded.

Focus group discussions posed an opportunity for follow-up questions regarding the emerging theory, but from a different angle, i.e. through group discussions. A theoretical sampling approach was taken for the FGDs, informed by a preliminary theory identified during data analysis of the interviews and observations. Preliminary findings suggested that health care providers may have their own tacit uses for data and health information beyond HMIS data. Still, given the limited staff numbers and availability, the sample consisted of roughly the same participants as for the interviews.

Recruitment of participants for initial interviews and observations was carried out with the hospital matron's/patron's help. They introduced the data collectors to maternity care providers but played no role in the recruitment for FGDs, for which maternity care providers were approached separately.

Data collection

Interviews with i) mothers, ii) their companions and iii) maternity care providers, as well as observations of intrapartum care (data collection 1, February 2021) and co-design workshops including focus group discussions (data collection 2, June 2021) (Figure 14) were conducted in two of the four research hospitals in Tanzania to inform the ALERT intervention design (138).

Topics and prompts for study III, related to maternity care providers' perception of data, its use and purpose, were included in the overall topic guide for maternity care provider interviews and for observations for ALERT Tanzania, which was piloted in two hospitals outside the research area. The overall topic guide contained subjects including 1) respectful care, 2) communication, 3) admission processes, 4) monitoring during labour and childbirth, 5) companionship and 6) professional perceptions of maternity care providers. I had been involved in the design of the topic guide and its piloting, but not in its translation to Kiswahili, which was undertaken by ALERT team members from MUHAS, but which I reviewed together with other team members and data collectors.

All data collectors, including myself, received a 1-day training on the topic guide, data collection standard operational procedures and non-participatory observation. Analysis of the overall data from the formative research within work package 2, in which I am also involved, is ongoing.

I collected data in the public facility together with three male colleagues, sub-contracted by MUHAS. All three had extensive experience in qualitative data collection. I conducted most of the interviews with maternity care providers and three observations in this facility. We held reflexive de-briefings after every day of data collection and twice with the overall team and work package leaders via zoom. The data collectors' team in the private-not-for-profit facility consisted of three female and two male colleagues, three from within the ALERT team and two sub-contracted by MUHAS. Peer check meetings were conducted in a similar way by that team. After data collection, audio tapes were transcribed in Kiswahili by five of the data collectors and two sub-contracted transcribers from MUHAS. Quality control of selected transcripts versus the original audios was done by a senior researcher from MUHAS.

Analysis

Preliminary analysis consisted of inductive line-by-line coding followed by focused coding of four transcripts undertaken in collaboration with a senior researcher from MUHAS, for which we used three transcripts of observations from one hospital for triangulation. This analysis informed the initial hypothesis that maternity care providers do not use numeric routine health data for their daily work, because they need qualitative data for clinical care, which they generate in a parallel narrative system. I also confirmed what I had noted earlier that 1) maternity care providers were not enabled by their working environment to monitor mothers and especially newborns according to international standards. 2) Partographs were still completed, often even retrospectively instead of health care providers using this tool as a means to demonstrate their challenges with monitoring to the management. These two aspects allowed for the development of theory-based questions for the second round of data collection using focus group discussions during a co-design workshop in June 2021 (Figure 14).

During analysis, frequent peer checks were undertaken with three colleagues from the ALERT team in Tanzania and with one of my supervisors. These reflexive sessions assisted in uncovering the multiple dimensions that documentation and data use have in the realities of maternity care providers in their context. In addition, a member check was performed with maternity care providers from all four ALERT research hospitals since it was important to represent their voices (160) and not just write about them.

4.6.4 Study IV

Aim

To understand how health care policymakers perceive and experience working with data, data systems and the introduction of digital technology related to the governance of health management information systems.

Design

For this qualitative study reflexive thematic analysis grounded in social constructivism was applied to 16 in-depth interviews with subnational and national managers familiar with using or implementing (digital) routine health information systems in Tanzania. Several theories on the use of power inspired the design and analysis, including VeneKlasen and Miller's concept of power typology (161) and the writings of Foucault (162) and Max Weber (129). Eventually, Lipsky's theory of Street-Level-Bureaucracy (124) was chosen because the concept of discretional power seemed very appropriate, given the assumption that health information systems constitute complex adaptive systems (99) and its application in Tanzania and other sub-Saharan African Countries (125).

Study population

Health care managers engaged in digitalization or use of health information systems at three managerial levels (national, regional and district level) were the study population for this research.

Sampling and recruitment

In this research, purposive sampling was applied to identify managers with a wide range of experiences within the topic of interest. A stakeholder map was prepared of important units and departments of the two ministries, MoH and PO-RALG, given that both are involved in the development or implementation of key areas of national policy regarding digitalization and health information systems. Acknowledging the risk of desirability bias in a public and political setting, especially at national level, external gatekeepers were chosen from two organizations supporting aspects of health information system development, the *Gesellschaft für Internationale Zusammenarbeit* and IHI. Staff from both organizations reviewed the stakeholder map, after an introduction to the research and its aim and objectives, and suggested potential participants, with presumed in-depth information regarding the topic guide. Potential participants from the national level were initially approached by email and the study information, ethical clearances and research proposal were shared with them electronically. Given their work schedule, not all responded directly so follow-up was undertaken by phone, at which time any questions could be answered.

Potential participants at regional and district level were directly approached by the ALERT coordinator for AKU located in the research area. They received written and oral information and had the opportunity to ask questions. Of all health care managers contacted, none refused participation and all but one high-ranking manager at national level were interviewed. The latter was engaged in a series of political meetings at the time of data collection and was travelling later. Information power (51) was used to monitor the quality of the data set. Interviewees were carefully selected, with their knowledge and experience related to the research question in mind. Many of them were familiar with me from my previous work, so rapport was well established.

Data collection

I collected the data for this study in October 2022 at subnational level and in January 2023 at national level (Figure 14). Eight interviews were conducted at each level. Although I could not interview one participant from national level due to his schedule, another high-ranking manager volunteered when I was passing through his department to conduct another interview. Two participants, one from national and one from subnational level, did not give permission to be recorded. Notes were taken instead, following consent.

Analysis

As in Study I, the six steps of reflexive analysis as described by Braun and Clarke (152) guided the approach to analysis. Given the ample body of theory that exists on health governance and power practices and based on the methodological flexibility of reflexive TA (163), we found this approach fitting for this study. It allowed for inductive coding to see to which theory the data would lead us. Additionally, all members of the research team for this study had long-standing experience with stakeholder management and research including politicians. The reflexive processes stipulated by this form of TA allowed us to include these experiences in a meaningful way (152).

A senior qualitative researcher from MUHAS and I coded four transcripts separately, including transcripts from all managerial levels. The aim here was not to reach consensus on codes but rather to incorporate into the analysis a variety of perspectives based on our different positionality. We identified initial patterns of meaning reflected by clustered codes. I then coded the entire data set with frequent reflexive peer discussions, during which we discussed initial themes which were then developed further during subsequent sessions. We increasingly discussed various theories related to power use and agency until agreed that Street-Level-Bureaucracy theory developed by Lipsky (124) was best suited to our data.

4.7 Ethical considerations

All research including human subjects must follow the Declaration of Helsinki, initially put forward by the World Medical Association in 1964 (164). This section will follow the ethical concepts of medical research: i) autonomy, ii) beneficence, iii) harm and iv) justice as described by Beauchamps and Childress in 2001 (165).

Autonomy

All research subjects should participate based on adequate information, voluntarily and without being influenced by either researchers or a third party. The main process safeguarding this autonomy is informed consent. All participants who took part in the qualitative parts of the four studies received written and oral information in Kiswahili about the aims and objectives of the respective studies as well as about potential benefits and risks of the method they were asked to participate in. Ample time was allowed for questions and answers. Information and consent were carried out as a two-step procedure to allow time to reflect on participation. Participants gave written consent to their participation and recording. To ensure voluntary participation, researchers emphasized repeatedly that they could withdraw their consent at any time. Participants did not receive any financial incentive for participation, but transport fees were reimbursed to limit financial harm to participants.

Assent to observations was acquired for study I and III. Regional and council health management teams, as well as those in charge of health facilities gave their assent for the observations to take place in their facility. Patients were informed about observations being conducted during a named period together with the aims, benefits, risks and mitigation measures of the study. They were also asked for consent if shadowed. Patients received information on observations requiring assent when entering the maternity ward, and the right to opt-out was emphasized. Posters with this information were displayed in the hospital well ahead of data collection. Before the start of the study, maternity care providers were informed as a group about the research and provided assent to being observed. On the day of observation, maternity care providers on duty, were again asked for their assent.

Study II used data on health service provision that is routinely collected during each health care encounter. This data is normally used for health service planning and for reporting against targets at national and international level. The study used this data from two different data sources, SPT and DHIS-2. The issue of individual informed consent or assent from authorities for routine health data use was submitted to all relevant ethical institutions as part of the proposal and discussed during stakeholder consultations with health authorities in Tanzania and assent was provided after the study aim, benefits and risks were explained. No amendment was requested from ethical boards with regard to this approach.

Beneficence

Research suggests that high-quality and timely data is important for the planning and prioritization of health care services. Participants had no direct benefit from our research at the time of consent. Hospitals, district and regional health authorities and the MoH or PORALG, however, could benefit over time, e.g. through the introduction of evidence-based digital technology that may improve workflow and reduce unnecessary duplication of documentation. A better understanding of social dimensions and practices regarding health information systems could assist policymakers in designing more efficient and enabling working environments for routine health data collection and processing in the future.

Harm

Three main categories of harm were identified for the four studies included in this research; i) social harm to participants due to confidentiality breaches, ii) mental harm to participants and researchers through remembering or witnessing potentially traumatic situations related to the environment of patient care in included health facilities and iii) physical harm to participants and researchers during data collection in pandemic times.

Social harm could arise for participants in the research, through being identifiable and therefore associated with negative comments about the health care system or their managers or the description of malpractice. This is because the numbers of health care providers working in the included facilities were limited. Since all were eligible for participation due to their involvement in health care and routine health data collection, it could potentially have been easy for superiors, the public or policymakers to identify which health care provider participated and what they said or did during interviews, focus group discussions or observations. To mitigate these risks, confidentiality was ensured by; i) de-personalization of all data included in data collection, management and analysis, ii) choice of locations for interviews and focus group discussions being led by participants based on adequate audio-visual privacy, iii) data security during data management.

For qualitative data sets, all personal and location names were removed from transcripts. Information for reporting and publication was synthesized at a highly aggregated level, making it impossible to identify individual participants. Participants from study IV, especially from national and regional level, are considered policymakers with public interest in their views and work. Potential participants were identified using the researchers' previous experience with stakeholders related to maternal health care and digitalization and by using external gatekeepers. While one of the co-authors of the manuscript is a health care manager at PO-RALG, he was neither involved in participant selection nor in transcription and coding, but only in data analysis at thematic and latent level, since his input as peer check was considered very important. All participants were informed about his involvement and how their confidentiality was protected during the first round of information provided about the study.

Locations for interviews and focus group discussions were chosen together with participants and to their convenience. Measures were taken to ensure audio-visual privacy.

Transcripts were stored on a password-protected personal laptop. Transcripts were pseudonymized by replacing names with individual coded identifiers. The list of identifiers was kept separately from transcripts. Where transcripts were shared, this was done via personalized and secured link to the KI-server. Data sharing was formalized through data sharing agreements for all data moved outside Tanzania except for study IV for which data was analyzed in-country. For study I-III data sharing was limited to co-authors.

At the time of Study I and II, data security was only emerging as a topic of concern in the country with the introduction of GoT-HoMIS which is based on individualized data while previous data systems such as DHIS-2 use aggregated data. Data security was therefore discussed intensely with government representatives of all administrative levels for the overall ONGEZA project, and stakeholders agreed to host the data on the external SHIFO server, because the organization had experience with data security for SPT data from previous projects in Uganda and The Gambia. The SHIFO server was secured via access rights and multi-factor authentication. All data in the database was depersonalized via the unique identifier, which was removed when data sets were shared with research team members. The original SPT forms with client names were kept in the respective health facilities in a locked cupboard.

Mental harm to participants could potentially occur through remembering traumatic events experienced while providing maternity care in the challenging settings of the two research hospitals, e.g. a perinatal or maternal death, or disrespectful treatment by superiors, patient families or the public. Data collectors were trained about these risks and mitigation measures. All had counselling skills to provide immediate care in such an event, before linking the concerned participant to the mental health services of the district. Personally, I am experienced in counselling clients and colleagues in such events. Although no participant experienced visible post-traumatic stress during IDIs or FGDs, during one of the FGDs maternity care providers voiced a need for regular, general counselling following the session.

Mental harm to observers, especially those with a medical background, could potentially occur when witnessing a situation where either inappropriate treatment was applied, a health care provider demonstrated misconduct towards a client, or the observer possessed the clinical skills to solve a situation which the health care provider did not have. These scenarios were included in observers' training and mitigation measures were discussed: Data collectors were instructed to report cases of negligence or abuse to the maternity ward nurse in-charge who could then, in a sensitive manner, address the issue with the health care provider concerned. A protocol to handle medical emergencies was agreed on. In such cases, observers were instructed to only intervene in a life-threatening emergency and otherwise ensure that the most senior person from the department was called to handle a case. During daily debriefing sessions held by each team, incidents could be discussed for post-trauma- counselling and adaptation of protocols.

During the COVID-19 pandemic there was a potential risk of physical harm to data collectors and participants from SARS-COV transmission during data collection. Research restrictions issued by the National Institute for Medical Research delayed the roll-out of SPT trainings so that the cohort for study II did not reach the expected size of a full district. Although restrictions were lifted in 2020, data collection in research hospitals for study III took place against the background of a new surge in infections. It was difficult to assess the situation since there were no official statistics on COVID-19 prevalence at that time, but the data collectors decided to proceed after a careful risk assessment of the locations and with the necessary precautions in place.

Overall, the benefits of the research outweighed the potential risks after risk assessment and the development of mitigation measures.

Justice

Two aspects of justice are considered relevant for the four research studies, i) the right to health care and ii) the right to high quality data for decision-making and health care prioritization.

There was a risk to the right to health care for patients who did not wish to be part of the observations conducted in included health facilities. Although they were informed about the observations taking place, choice of healthcare facility was sometimes limited, given the remote location of some facilities. Information was therefore disseminated at a prior visit to the facility so that patients would know about the study well in advance. Furthermore, during observations, patients who were present were also asked for consent.

Although health care providers consented to being followed, health care is not predictable and situations may arise where the presence of an outsider may disrupt clinical services or unduly harm the client, e.g. in case of i) emergencies, ii) the delivery of a difficult diagnosis, or iii) a person's death. These situations were discussed during observers' training and they were instructed to leave the health care provider they were shadowing in such cases, until the associated task was completed and observer presence was cleared by the health care provider. Interviews and focus group discussions were conducted with health care providers who were off duty to minimize any impact on health care provision.

It was expected that the study results would inform the government's and health care managers' decisions on conceptualization and implementation of the health information system and its digitalization so that the right to high quality routine health data for decision-making can be improved.

4.7.1 List of ethical approvals

All four studies received ethical approval from i) the Ethics Review board of the municipality of Stockholm, ii) institutional review board (IRB) of the respective partner organizations of the ONGEZA and ALERT projects and iii) the National Institute for Medical Research in Tanzania. Where applicable, ethical clearance from IRBs and NIMR in Tanzania were extended to continuously cover the research period.

Study I & II

- Institutional Ethical Committee of Ifakara Health Institute (IHI/IRB/No.20 -2018, IHI/IRB/EXT/No. 28-2020, IHI/IRB/EXT/No. 36-2020)
- National Institute for Medical Research (NIMR/HQ/R.8a/Vol. IX/3018 and NIMR/HQ/R 8c/Vol. I/1632)
- Ethics Review Board of the municipality of Stockholm (2019-04022 Gk), Sweden.

Study III

- Institutional Ethical Committee of Muhimbili University of Health and Allied Sciences (MUHAS-REC-4_2020-118)

- National Institute for Medical Research (NIMR/HQ/R. 8a/Vol. IX/3493)
- Ethics Review Board of the municipality of Stockholm (2020-01587 Gk), Sweden.

Study IV

- Institutional Ethical Committee of Muhimbili University of Health and Allied Sciences (MUHAS-REC-02-2022-975)
- National Institute for Medical Research NIMR/HQ/R.8a/Vol. IX/4009
- Ethics Review Board of the municipality of Stockholm 2020-01587 GK

4.7.2 Reflections on my role in the research and research cooperation

During my research, I had the opportunity to contribute to i) the design, data collection, analysis and reporting of two very different implementation research projects, ONGEZA and ALERT, and ii) to academic teaching of master's students at Karolinska Institutet. While the first research project was a partnership between one Tanzanian and two Swedish institutions, the latter was a multi-national, multi-disciplinary consortium. In both projects I was involved in research and contributed to project management and implementation. Since the ONGEZA project was conducted in Tanzania only, project management took place mainly in Tanzania, where I functioned as a member of the local research team. Further, I represented Karolinska Institutet in administrative and financial tasks and was involved in preparation of dissemination material and stakeholder meetings. For the ALERT project, I contributed to all nine work packages on behalf of Karolinska Institutet. I was part of a team of three consortium members, who developed the intervention based on a synthesis of results from the formative phase. In addition, I served as an advisor to the Tanzanian ALERT team, supporting formative research and financial administration, e.g. financial forecasting and the development of operational plans.

While I am an experienced project manager, I was initially a relative novice to research. It was thus often easier for me to carry out project management tasks than data analysis and academic writing, which initially delayed my output in this area. With time and support from my supervisors my academic confidence and independence increased, and I caught up with data analysis and development of scientific articles and thesis writing.

5 Results

This chapter will synthesize the results from Study I-IV according to the thesis framework (Figure 9). The aim of this section is to describe the social practices related to different domains of the framework, to shed light on how these practices affected the domains' complexity in the case of the health management information system in Tanzania. Using the example of *Smart Paper Technology* and other systems for routine health data collection and processing existing in Tanzania, such as HMIS and GoT-HoMIS, I will then illustrate how these social practices may affect digitalization of health information systems. Each domain of the thesis framework is introduced with the main findings, followed by elaborate results and supporting data or quotes.

Table 4 below summarizes the thesis results based on the thesis framework.

Table 4 Results summary

Research aim	**Framework domain**	**Main results**
To understand the social practices involved in generating and processing routine maternal and newborn health data using paper-based and digital tools within the health management information systems in Tanzania.	1: The condition	Semi-digitalized data processes within the current health information system are complex and multi-layered, providing opportunities for data modification and discretionary interpretation of implementation strategies.
	2: The technology	Technology-related reasons for non-adoption were common among health care managers, while contextual reasons dominated failure of sustained institutionalization of SPT technology at health care provider level. For the existing HMIS and DHIS-2 technical and contextual reasons were important at both levels.
	3: Value proposition	Health care providers and managers assigned different values to the novel SPT system and to the health management information system in general.
	4: The adopter system	Health care providers preferred narrative documentation and SPT over HMIS documentation. They appropriated SPT and HMIS to display their professional role as maternity service providers. Health care managers' level of adoption of the novel technology depended on perceived benefits for their own agenda.
	5: The organization	The health care system lacked a data culture that aligned policymaking with implementation.
	6: The wider system	Discretionary interpretation of policies and contextual challenges influenced policy implementation by lower-level managers and health care providers.

Research aim	Framework domain	Main results
	7: Continuous embedding and adaptation over time	The scope for adaptation of SPT technology itself was limited, but there was leeway for adaptation of the overall SPT system to better align with the values and norms of different actor groups. Socio-culturally rooted perceptions of health care providers with regard to data appropriation and the value assigned to numeric data was not amenable to technology and system adaptation.

5.1 Domain 1 – The condition: Data processing within the health management information system in Tanzania

Semi-digitalized data processes within the current *health management information system* are complex and multi-layered, providing opportunities for data modification and discretionary interpretation of implementation strategies.

5.1.1 Data processes of the semi-digitalized HIS were perceived as time-consuming and complicated.

Study participants at all health care levels described the current semi-digitalized HMIS as cumbersome with consequences for data quality and availability and use of their time (Study I, III, IV). Health care providers described the burden of completing register books, tally sheets and monthly reports, while lower-level managers complained about manual data entry from report forms into DHIS-2 (Study I, III and IV). District managers also described their time-consuming engagement with ensuring data quality by i) calling facilities, ii) visiting facilities to review registers, or iii) asking health care providers to bring registers for monthly review and data entry (Study I and IV). The HMIS comprised of several databases and sub-systems in which interfaces were often missing. This often led to duplicate data entry and discrepancies between different databases (Study III and IV).

5.1.2 Health care providers saw themselves as data producers and appropriated data for their own purposes.

Health care providers perceived themselves to only be generating data for managerial use (Study I and III). National and subnational managers were aware of this view but had no immediate solution (Study IV). Unpredictable availability of funding and other resources led to the use of discretional rather than institutional power in process implementation (Study IV). Facility and subnational managers stressed the importance of complete and timely reporting over consistency (Study III, Study IV). As a result, health care providers added data retrospectively, e.g. for the partograph (Study III) or tampered with figures (Study I and III). Health care providers described line managers' complacency with this behavior to report complete data upstream (Study III). Health system bottlenecks also seemed to facilitate alteration of data, e.g. increasing the number of patients receiving a certain commodity that was out of stock (Study I).

Despite the availability of data in register books at health facilities, health care providers did not make use of it for health care quality improvement (Study I, III, IV). Participants from study I reported that they could not use the data since they were unable to analyze it.

> *"Charting a graph [from data] is another issue. Because in most cases the data person from the district team creates these graphs. For us in the facility, to say we can prepare our data or a report ourselves, like creating a graph or doing the analysis, we can't do that." (FGD3_post-intervention, Study I)*

Findings from Study III suggest that health care providers viewed numeric HMIS data as suitable for service planning or performance monitoring. For their own clinical work or quality improvement, they preferred narrative documentation that they had often designed themselves. This further increased the complexity of care documentation and routine health data collection.

5.2 Domain 2 – The Technology: Smart Paper Technology and Health Management Information System

Technology-related reasons for non-adoption were common among health care managers, while contextual reasons dominated failure of sustained institutionalization at health care provider level.

For the existing HMIS and DHIS-2 technical and contextual reasons were important at both levels.

5.2.1 SPT was considered acceptable, usable and feasible as compared to HMIS.

Study I and II describe the implementation aspects of a novel semi-digital technology to support routine health data collection and processing. Findings from these studies underline the complexity of technology introduction and institutionalization.

The SPT system was deemed to be feasible and useful, especially among health care providers. Their descriptions provide important information on how data entry formats could look, to be well accepted by data collectors in similar settings. Health care providers and managers alike identified several advantages of SPT forms, and its processing system as compared to HMIS: i) Forms mostly required a tick rather than hand-written information and ii) the content was known, thus there was iii) little need for extensive training. Related to this, iv) little support in completing the forms was needed by health care providers, with participants of Study I considering the mentoring via a WhatsApp group sufficient to complete the forms well.

> *"Because many things in SPT come from HMIS, we had ample time to learn. And I, for my part, did not see that it was something difficult after understanding what SPT is about. Because many things we take from HMIS, we just fill in the paper. So, I did not find it difficult at all." (FGD3_post-intervention, Study I)*

Managers initially noted the system's potential to save time and human resources, previously spent on manual data verification and digitization.

> *"Now for HMIS that means one has to enter everything into the system but with this [SPT] it's straight forward, you just scan. This can reduce the number of people [involved], it will help other people to perform other tasks." (IDI1_follow-up, Study I)*

5.2.2 Limitations to data access impacted usefulness.

Despite initial enthusiasm, managers described problems accessing the SPT dashboard and also did not feel adequately trained to do so. Other than lack of knowledge, access problems were related to structural issues such as insufficient bandwidth for network availability and access codes which were generated by the technology supplier (Study I).

Additional logistical measures were required for forms to be transported to the district capital for scanning and back to facilities afterwards. Those in charge of health facilities and district managers had difficulties implementing these, due to a lack of transport and funding. Quantitative results from Study II support these qualitative findings demonstrating a decreased timely availability of SPT forms available for scanning (34%) (indicator 4a, table 2 Article II).

5.2.3 Health care managers failed to benefit from additional knowledge generated by SPT.

The main advantage of SPT is the additional availability of individual data, instead of aggregate data only, at manager level. This could have increased their efficiency in data verification and allowed for both individual and aggregated data to be used to monitor service coverage for different sub-groups. Otherwise, SPT mostly generated the same data as HMIS, and healthcare managers were used to working with aggregate data for upstream reporting. Duplicate data entry into both systems was maintained during the study period, thus all data needed for reporting was present. Consequently, the additional value for data analysis and synthesis provided by the new technology may have been less obvious to managers. Due to i) access difficulties, ii) discrepancies between SPT and DHIS-2 summary reports and iii) possibly the health care system's emphasis on data completeness over consistency, the benefits were not realized (Study I). Therefore, the SPT system did not influence their data use beyond aggregate coverage indicators which could be generated in DHIS-2, where access was simpler.

5.2.4 Health care providers' efforts to embed SPT were not supported.

Findings from Study II suggest that low SPT data completeness may have been an important reason for discrepancies between the two summary reports: Between 2018 and 2020, SPT data from the 13 included facilities showed trends for 1st ANC visits, number of deliveries and number of PNC visits that were consistently below DHIS-2 numbers (Figure 16, Figure 17, Figure 18).

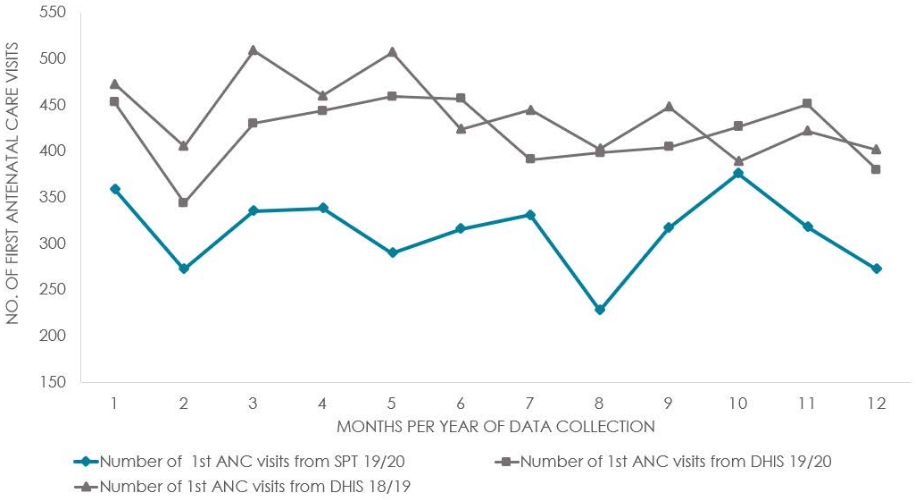


Figure 16 Trends in numbers of antenatal care first visits over one year for SPT in relation to DHIS-2 2018-2020. SPT trends highlighted in petrol.

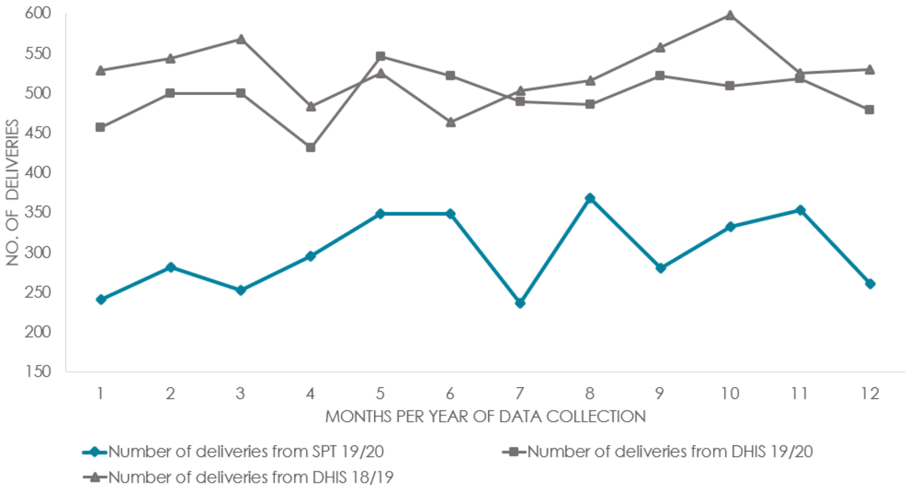


Figure 17 Trends in numbers of deliveries over one year for SPT in relation to DHIS-2 2018-2020. SPT trend highlighted in petrol.

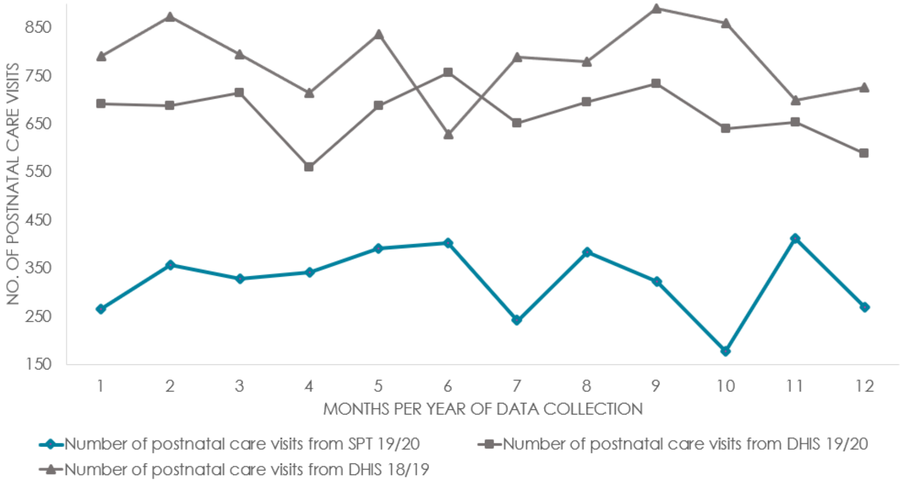


Figure 18 Trends in numbers of postnatal care visits over one year for SPT in relation to DHIS-2 2018-2020. SPT trends highlighted in petrol.

Moreover, indicators on internal consistency of the database, based on disaggregated cohort data such as related maternal health indicators, i.e. number of deliveries and oxytocin use postpartum (indicator 6, table 2, Article II), showed higher levels of consistency for SPT as compared to DHIS-2 data sets. This finding may also hint at an external effect rather than a factor implicit to the technology, given that the use of the SPT unique identifier was 100% for LC. Health care providers may have forgotten to enter a client into the new system, but this result could also indicate that once they had started a form, they completed it. But quantitative results do not allow an inference. Participants' descriptions from Study I of the form's lean design and the ease of completion may underscore this.

In addition to the burden of data entry into two systems, district managers linked the discrepancy in reporting to behavioral traits among health care providers and logistic issues. Although mitigating both issues lay in their realm of power, they seemed unable to act.

> *"They have not reached completeness that is true. They may have forgotten to enter all [clients] and this is a question of commitment. Once this has been improved, everything will arrange itself. The second [reason] is the constant supply of forms, so that you don't miss out on any day. Because if you miss [SPT forms], there must be a difference." (IDI5_post-intervention, Study I)*

Health care providers might have benefited from close supervision to improve completeness, but managers failed to provide additional visits to support SPT data entry (Study I). Findings from Study IV report similar problems for general data quality assurance in HMIS, often related to lack of funding.

In this context, it is notable that in several instances health care providers seemed to assign agency to the SPT-system itself, by ascribing supervisors' tasks to it.

> *"Because this form criticizes you. If you leave a lot of gaps, it is not good. This means you must look for the Hemoglobin machine, you will look for the urine [sticks]. Because all these exis; are things that are available." (FGD2_follow-up, Study I)*

5.2.5 Different tools for routine health data collection and processing did not influence health care providers' data use.

Despite health care providers' preference for the new system, SPT did not influence their data use either (Study I). Participants reported that they could not use SPT data because it was not continuously available at facility level. They did not have access to the dashboard and described logistical issues related to transporting forms back to facilities.

> *"And you can't use this [SPT form], we don't use it because at the end of the month, they take it, if it's gone, it's gone, so concerning the [monthly summary] report, you go back to HMIS." (FGD1_follow-up, Study I)*

HMIS registers remained in facilities but register data was not used either, other than for annual planning (Study I and III). Health care providers' need for narrative data, described in Study III, remaining unaddressed by the system, may have led to SPT data use similar to what they reported for HMIS. This assumption, together with the issue of district managers' lack of agency to support data collectors, underlines the importance of contextual factors beyond the technology itself.

Findings from Study I and III, including managers' failure to see the importance of individual data, suggest that barriers to SPT data use may be related to the general lack of analytic capabilities of technology adopters.

5.3 Domain 3 - Value proposition: Perspectives on perceived value generated from technology and health management information systems.

Health care providers and managers assigned different values to the novel SPT system and to the health management information system in general.

5.3.1 Healthcare managers expected improved data quality, revenue and performance control.

National-level managers emphasized the prioritization of health data systems and digitalization on the national agenda (Study IV). They had a vision of what could be achieved through digitalization and had considered the components needed within health management information systems iteratively, learning on the way.

> *"So, when I am old, I know I will be served by much better digital systems in health facilities! So, we are progressing well, and we will reach where we intend to!" (IDI 14_national level, Study IV)*

National healthcare managers participating in Study IV working directly with HMIS or other data systems described their data needs as mainly related to quantitative, or numeric coverage data for performance measurement, planning and political use. These managers agreed that reducing the number of existing systems to a few digital systems and focusing on electronic medical records would solve many of the current system's problems of integration, data fabrication, data availability and low data quality. Apart from anticipated improvements in data quality described by participants of Study IV, there were also hopes that the various data needs of more actors, e.g. health care providers, could be covered by these electronic registries.

> *"So now what are we going to do? What we need to do is to see if there is one system that will at least answer all the people's concerns by at least 80 or 90 percent. That means I have a health recording system, an EMR [Electronic Medical Records] that will take all the patient's information. (IDI 15_national level, Study IV)*

In addition, control over facility revenue through integration of systems was mentioned by national managers as a very important goal of digitalization.

> *"...Issues around cash have decreased. You will find that even for financial management we use FFARS [a digital finance reporting system]. The system is ready for accounting and reporting, ready due to digitalization. I am here but I can manage a facility in district X. I will see how much district X spent yesterday, the amount they withdrew for a certain activity. That's why they [the Government] have been insisting." (IDI 10_national level, Study IV)*

Subnational-level managers in Study IV argued for digitalization in terms of improved control of health care providers' service provision.

> *"Because, for example, I see that a patient has passed [at various points of services], it is easy to ask the patient and find their name in the system. If the patient is recorded and I go to the pharmacy [section in the system] to see if the patient is given medicine and I go to the laboratory [section in the system] to see if the patient has received tests, it is easy with GoT-HoMIS." (IDI 7_subnational level, Study IV)*

District managers described SPT in a similar way (Study I). They described performance not only in terms of health care providers doing their job, but also as use of available resources for patient care only. Overall, from a managerial point of view, there were compelling arguments to drive digitalization forward.

5.3.2 Full system ownership was a prerequisite for the value proposition of the health system.

Study IV findings may also shed light on why SPT implementation was not more supported by managers in terms of supervision, logistics and advocacy for the removal of duplicate data entry at the research facilities. Several national-level managers voiced interest in the new technology, especially for lower-level health facilities, as an interim solution until structural challenges related to digitalization were dealt with.

National agendas had moved from previously accepting technical solutions, fully operated from outside the country, for the sake of digitalization, to the current view that the government should fully own a technology from the start, for sustainable scale-up.

> *"So, there are those challenges that you are provided with resources, but you are told: Here are solutions you are going to use. So, for us this is difficult, because you find that you are given a solution that has been built abroad, that is only brought in so that you use it...We tell them [donor organizations or system developers]: We have gaps in this area, if you want to help us or invest in the health sector, the challenges are in this and this area. So, when they come, they... invest in the area that we have prioritized. If it is a [data] system, we provide the technical know-how: We want this specific system, use this specific technology, do data entry using this system. We are in the driving seat." (IDI 14_national level, Study IV)*

The technology supply model for SPT foresaw a gradual phase-over to the government. This interfered with the above agenda on data sovereignty, which was based on national managers' previous experiences with stakeholders building data silos to the disadvantage of official systems.

> *"... A stakeholder can come with a resource...They decided to start at facility level: I have funding, I want you to do 1,2 3. I want data for maternal and newborn [care], I have developed this capture tool! So, they start there while the central ministry is not aware of what is going on at the facility. So, you see the employees have stopped filling in DHIS-2, you ask them why? They tell you: We have this tool...". (IDI 14_national level, Study IV)*

Despite the accounts of national managers about their subnational-level colleagues' frequent engagement with donor-driven digital tools, subnational managers acted differently regarding SPT and did not support its consistent use. This different behavior may be related to district managers' failure to see the system's output as a useful additional data source in terms of data analysis and synthesis (Study I) and data quality (Study II). This may also depict their dynamic interpretation of national agendas depending on their own perceived benefits.

5.3.3 Health care providers valued SPT improvements for clinical work but preferred fully digitized systems to feel protected.

As described under Study I, health care providers acknowledged the benefits of SPT use for i) their overall workload, ii) time spent with clients, and iii) workflow. They therefore made a collective effort to integrate the new technology into daily work routines. Results from Study III suggest the potential for embedding SPT into the creation of their professional narrative, and Study I findings appear to support this:

> *" To start with, for SPT we have organized ourselves very well, because first of all, we don't want to be criticized every day. Because we are people who know what they do." (FDG 2_follow-up, Study I)*

In addition to the immediate SPT benefits for health care providers' workflow, findings from Study I also suggest that they saw value in the use of SPT's unique identifier, to quickly retrieve information on service provision when clients returned. This may have supported their feeling of being protected against social and legal consequences of negative childbirth outcomes, as described in Study III, because they knew that their information was captured digitally in the end. Findings from the same study describe how health care workers saw full digitalization as a means to improve archiving. In contrast, participants from Study I spoke about their fears that SPT forms could get lost before the scanning process.

> *"I can fill it [the form] for this mother. I said, let me come back and put it in a file. Because there is no proper filing system, like clipping or punching, it is very easy to get lost. Through bad luck, it may be falling down, and a cleaner is coming, who does not understand the importance of this, they do not pick it up, they dump it. But the [register] book, you cannot dump that." (FGD1_follow-up, Study I)*

5.4 Domain 4 – The adopter system: Health care providers and their managers

Health care providers preferred narrative documentation and SPT over HMIS documentation but also appropriated SPT to display their professional role as maternity service providers.

Health care managers' level of adoption of the novel technology depended on perceived benefits for their own agenda.

5.4.1 Health care providers preferred SPT over HMIS because it increased efficiency.

Health care providers used official data sources, like the HMIS together with narrative documentation to embody and protect relationships with different groups, i.e. their i) line managers, ii) higher level managers, iii) each other, and iv) the community, as described in Study III. They primarily saw themselves as health professionals and not necessarily as data collectors, despite knowing that routine health data collection was part of their work. They therefore tended to prioritize patient care over documentation and felt that they were collecting data for someone else's use (Study I and II).

Participants' vivid description of their time and effort spent on documentation in HMIS (Study I and III) may suggest health care providers' lack of identification with their role in data collection, while quantitative findings from Study I indicated that the actual proportion of time spent on HMIS data entry was low compared to other tasks.

> *"This system is much easier than even in HMIS, because in HMIS you must fill in the register, you have to fill in the tally sheet, to fill in more than what you do in SPT... When reporting, we don't report in SPT, unlike HMIS, [where] you usually go back to the register and start counting again, so it takes time, you waste a lot of time in preparing HMIS reports, even the person who will enter [data into DHIS-2] they can call you that they don't understand some aspect here, or whatever: Go and start all over again counting in the register." (FGD_4_post-intervention, Study I)*

One participant described her view on HMIS data processing even intruding on health care providers' private time.

> *"Some have young children... So, will you prepare the report at nighttime? No. So you find yourself missing that time because there are many things and the OPD [Outpatient Department] report has many books to prepare not just one report." (FGD1 follow-up, Study I)*

Data collection in HMIS seemed to be perceived as very time-consuming. This was in spite of direct HMIS documentation only amounting to 11.6% of workload during the time-motion study before SPT-introduction and 9.8% afterwards, a difference that was not significant (adjusted p 0.627) (Study I). The decrease in time spent on HMIS could be triangulated with health care providers' description of increased efficiency, because they copied data from SPT forms into HMIS (Study I). In contrast, results from Study II suggest that HMIS data may also have been incomplete because of duplicate data entry.

5.4.2 Health care providers maintained their narrative documentation system after SPT introduction.

Indirect care documentation, referred to documentation not included into HMIS registers or SPT forms, such as that of the partograph or in patient files and was mostly hand-written, often in narrative form. It represented 15% of overall documentation before introduction of SPT and 14% thereafter (difference not significant) (Study I). This rather high proportion, as compared to direct care and HMIS documentation, may reflect the complexity of the additional narrative documentation efforts described under Study III, that were apparently maintained after SPT-introduction. Still, health care providers did not seem to mind the amount of time spent on that type of documentation. It was never mentioned by participants in Study I and was described as helpful in Study III.

One example for this narrative documentation was a book that nurses-midwives had started in one of the hospitals to document the clients' journey between maternity ward and theatre in case of caesarean section (Study III). They had spoken about it during interviews and explained further during the focus group discussion.

> *"Yes, yes, so that [the book] is what he [another participant] is talking about. It has the purpose [to document] if anything happens, we can state that this patient delayed a lot. It doesn't matter if we get bad or good results, we can state this patient delayed and where did we delay. You check the time of decision and then the time of preparation. If this is where we delayed, we make improvement there." (FGD 1, Study III)*

Health care providers from the other research site of Study III described a book in which medication was recorded for similar purposes. Documenting this narrative data made sense to them and fulfilled the purpose of improving services and demonstrating professional actions, something that numeric HMIS, but also SPT, could not do for them.

5.4.3 Health care providers appropriated SPT to display professionalism as maternity service providers.

Participants from Study I noted, however, that use of SPT could assist them in fulfilling the work they prioritized. During focus group discussions they described a decrease in documentation and a related increase in time spent with clients.

> *"Therefore, if you have many clients or you have planned to listen to each client for ten minutes, you could spend five minutes to fill in the normal HMIS and listen to them for five minutes. But nowadays you can spend one or two minutes to fill in the SPT and the other nine minutes are left for listening to the client." (FGD2_post-intervention, Study I)*

Whilst quantitative results from Study I support the increase in time spent with patients (26.9% before and 37.1% after SPT introduction, adjusted p 0.001), the changes in documentation time were not demonstrated to be significant at aggregated level (27.0% vs 26.4 %, adjusted p 0.763) (Figure 19). SPT only added 3% to the overall documentation time after its introduction (Study I). Whether this resulted from the technology itself and health care providers efforts to embed it into their practice or incomplete data entry cannot be inferred by the study design.

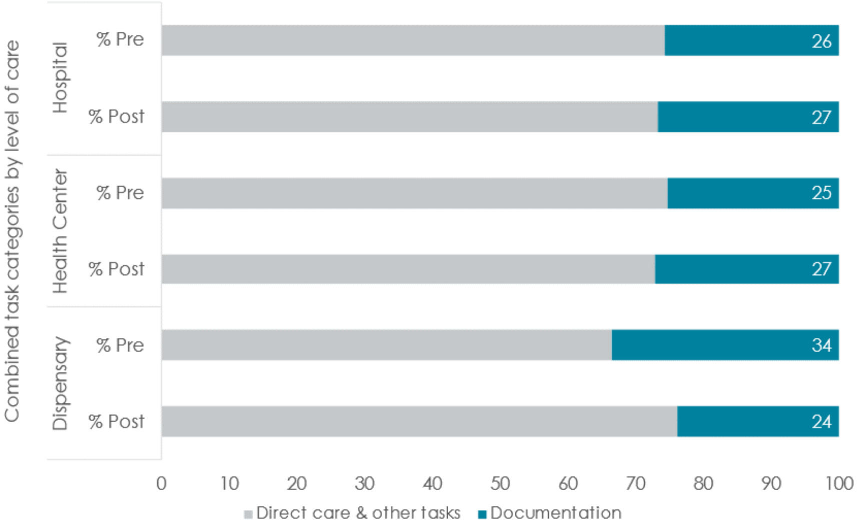


Figure 19 Proportion of time spent on documentation during an average shift by health care level

Differences significant at aggregate level for the total of three health facilities for direct care and other tasks, but not for documentation and not for the sub-aggregate levels, i.e. hospital, health center or dispensary.

Health care providers also observed that SPT helped them to fulfill their professional role in additional ways. Participants from Study I reported how their efforts to integrate SPT in their regular practices improved workflow, patient centeredness and even service delivery.

> *"I can say this about teamwork: It [SPT] facilitates [that] because it forces you to do everything that is important for the client. So, you have to assemble the equipment, like following up on a certain part. So, someone can send another person to look for the equipment and bring it there." (FGD1_follow-up, Study I)*

In order to complete the task, health care providers found creative ways to bypass health system bottlenecks to service provision.

> *"Sending a paper without ticking... That has really woken up a lot of people [health care providers] and some of them are asking for medicine in the neighboring facilities. Some I have never seen before but now we see them coming to ask for medicine here." (FGD1_follow-up, Study I)*

This quote suggests that the signature required on the form may have pushed health care providers towards completing all required fields, because their name could be seen. The data quality indicator related to internal consistency within the SPT data set (indicator 7, table 2, Article II), where the SPT system showed a better performance than DHIS-2, may also reflect this.

Overall, health care providers' lived experiences of the fit between SPT and their perceived professional role may have affected their value proposition in favor of SPT despite the obvious issues with data completeness and documentation time recorded during the time-motion-study.

5.4.4 Health facility managers had the potential to facilitate or hamper data collection and quality.

Health facility or departmental managers were the managers closest to health care providers and to the primary data before aggregation and many of them were responsible for monthly summary reports from the registers. However, they were also clinicians and colleagues of primary data collectors. In fact, they often collected data on service provision themselves and complied monthly summary reports.

Findings from Study III describe supervisors' complacency with retrospective completion of partographs for the sake of overall data completeness. In contrast, participants from Study I described their line managers' support of accurate SPT use.

> *"For us at the labor [ward], if you have not filled [all SPT forms] on that very same day, the in-charge goes through them. If there is someone who has not filled in, she writes down the names. You know yourself well, yesterday you treated maybe six patients, two of them you have filled, three are left [for you to fill]." (FGD3_follow-up, Study I)*

The quote above together with findings from Study III underline how crucial line managers' attitude is towards a data system or technology. This is also supported by results from Study IV in which some managers at national level realized the importance of this group for data quality improvement efforts.

> *"I personally think this needs sensitization starting with managers. Because the normal staff, doctor, nurse or anyone may have produced the data… You know, the data will not leave the facility without being seen by the in-charge. Now these supervisors themselves should be the ones if their staff has not seen it, then they should see that the data is not ok." (IDI 13_national level, Study IV)*

5.4.5 District managers did not see the advantages of the novel technology for data quality assurance.

District managers were hesitant to use SPT data for reporting and planning because they did not trust it. This was mainly related to discrepancies between SPT and DHIS-2 reports (Study I). They realized the issue may have been related to duplicate data entry into HMIS registers and SPT forms but did not show agency to advocate for correcting this.

> *"Concerning this study, if the ministry would have agreed to stop HMIS for a while so that this [SPT] could be done, I think it would give good results and even these challenges that we saw here, people forget, they fill here [SPT] while they have not filled there [HMIS]." (IDI2_follow-up, Study I)*

HMIS data entry was maintained during the study, so SPT did not produce any additional information for district managers. Data entry into the official system may have been prioritized because i) district managers felt that the established system worked for them and ii) to maintain reliable reporting to national level within an established system. Findings from Study IV may underline this. The national agenda on data quality assurance was filtered down well to the subnational level and implementation was built around the data quality assurance system at district level. District managers proudly described the detailed system that they had established to improve quality and make data from facilities fit for national and subnational use.

> *"In the past you could find that, from the 12 HMIS registers, someone (from the facility) would come with only six. But nowadays they know: If I don't come with all the registers, they will not receive me, so understanding is there". (IDI 5_sub-national level, Study IV).*

5.5 Domain 5 – The Organization: The health care system

The health care system lacked a data culture that aligned policy making with implementation.

5.5.1 The health care system failed to align different actor groups with different agendas on data, data quality and use, and digitalization.

Study IV results suggest that HMIS governance was characterized by i) the use of institutional power where enough certainty about intended outcomes and implementation strategies existed and ii) increased application of discretionary power and interpretation during conceptualization of systems or implementation of policies. Discretionary power was used to circumvent i) structural problems, ii) lack of resources and iii) contextual unpredictability. However, this approach led to a disrupted communication of important values and norms between data users (national managers), custodians (subnational managers) and primary data collectors (health care providers). All had different agendas in relation to data as described under Studies I, III and IV: i) Data use for change (national level, Study IV), ii) making the system work (subnational level, Study I, IV), and iii) maintaining professionalism in a difficult working environment (health care providers Study I, III). This lack of data culture may illustrate the potential for unintended consequences of policy implementation.

Managers of all levels described their overall perception of health care providers in terms of their fitness as data collectors. Results from Study IV describe their sympathetic perception of clinicians as overburdened and unable to see the importance of data for their work. This confirms what health care providers had reported about their own view of their role in Study I and III. Other managers thought that performing data entry correctly and using it was only a matter of commitment. Managers interviewed for Study I argued in a similar way as national managers about health care providers' commitment to entering data into SPT. While they considered the current generation of health care workers to be unfit for digitalization, they assumed that younger staff would share their own perception about the importance of data and would be better able to use the digital systems conceptualized by the government (Study IV).

> *"But if you ask about that old woman who is at the health facility. She says: I don't like this because even holding the computer mouse is a bit challenging. So, she cannot love it [digital data entry], she will hate it." (IDI 14_national level, Study IV)*

Findings from Study I suggest that other key attributes than age, such as analytic capabilities, that current health care providers were lacking, are crucial for data use. Assuming that younger professionals possessed these based on their alleged technological savviness may pose a risk to the scale up of data use. This may indicate that certain actors could be excluded from digitalization of the health system through decisions based on these assumptions.

5.5.2 Political pressure against the background of limited resources led to incremental implementation.

HMIS has been long been an integrated component of the Tanzanian health care system. Actors of all levels of health care seemed to agree that digitalization of routine health data collection was important. However, the reasons for this as well as data needs, perceptions about the value of data and related agendas seemed to differ: i) National managers recognized the country's need for data for performance monitoring and health sector development (Study IV). ii) Subnational-level managers looked at data mainly in relation to reporting to national level (Study II) and as a prerequisite for annual commodity and activity planning at their own and facility level (Study IV). iii) Health care providers needed data to demonstrate professionalism and maintain various social relationships (Study I and III).

National-level managers knew that there were contextual challenges to full digital roll-out in terms of i) funding, ii) infrastructure, and iii) human resources (Article IV), which led to unpredictability of progress and a decrease in system-technology-fit.

> *"There is pressure to implement. Regarding the issue of [data] systems, there is a lot of pressure to achieve it. But the factor that stops that pressure is resources. You find that you are developing a system, you reach somewhere, you stop, you wait again [until] next year, to come and continue there." (IDI10_national level, Study IV)*

Funding for health care implementation, including routine health data collection, was completely externalized, because it was managed by the Ministry of Finance and relied on donor contribution to a great extent. Participants from Study IV described its unpredictability in relation to planning and implementation, especially at subnational level. While this unpredictability slowed down the overall implementation process, changes were incremental and therefore not disruptive.

Participants from Study IV and III reported that due to the pace of implementation overlapping systems existed during transition periods, which often lacked interfaces with each other. This led to unnecessary duplication.

> *"So, what do they do? They likely just fill some random data to make it appear similar to the expected value…Now it becomes cooking. But what is possibly motivating them to cook the data? It is the difficulty of collecting the data. Doing double entry is very bad even if it was me, it would be very bad. So, there is something that motivates them to fake the data. If we address that, we will get data that is clean and trustworthy." (IDI 13_national level, Study IV)*

Findings from Study I and II illustrate the potential impact of this phenomenon on integration of new systems and technology and on data quality.

5.5.3 Implementation was characterized by contextual adaptation grounded in lower-level managers' positionalities and systemic bottlenecks.

National managers' own lived experiences with structural adversity in rolling out data systems informed their presumptions about i) barriers and facilitators for digitalization, ii) expected benefits and iii) solutions to anticipated problems. These may not necessarily have been in line with the experiences of subnational managers and health care providers regarding policy implementation. Findings from Study I and III describe the infrastructural, human resource and commodity challenges faced in routine health data collection, which led to discretionary adaptation of policy implementation (Study IV).

Subnational level managers were data custodians rather than users, mainly preparing summary data from facilities for national use, with elaborate procedures for data review described under Study IV. They often saw themselves as facilitators and problem-solvers for i) implementation, e.g. supporting health facilities in data use for annual planning, ii) data quality assurance and iii) communication between facility and national level. This role was based on important positionalities, e.g. the ability to triangulate numeric data with contextual information as described under Study IV. They shared many of these positionalities with those in charge of health facilities although the latter were closer to primary data collection. Study I and II results show how much power over adoption or non-adoption subnational managers potentially have. Findings from Study III describe how unchecked complacency of ward or facility managers could potentially influence policy implementation negatively.

Furthermore, some of the expectations associated with digitalization of health data systems may have been unrealistic. Both national and subnational managers agreed that digitalization was necessary because they saw health care providers unable to reliably ensure data quality. Many participants from Study IV suggested that health care providers' lack of commitment was the biggest obstacle to data quality, which could be mitigated by digital systems.

> *"The day we remove manual data entry for every facility we will have good quality data. This is an important aim of the ministry and in the health sector strategic plan 5 and we (therefore) need to digitalize the whole lower level of the health sector." (IDI9_national level, Study IV)*

This suggestion disregarded health care managers' responsibilities as supervisors, mentors and role models, their influence on health care providers' agency as well as the interconnectedness of the health care system and commodity availability described in Study I, III and IV.

5.6 Domain 6 - The wider system: Donor organizations, national and subnational managers

Discretionary interpretation of policies and contextual challenges influenced its implementation.

5.6.1 The government's push for digitalization ensured that important policies were in place.

In line with the national agenda on digitalization, necessary policies and guidance were in place. National managers agreed that policies only needed updating once outdated or when improvements were necessary (Study IV). However, several participants commented on the lead time for this process and on the resulting discrepancy between policy and reality.

> *"Unfortunately, something is still not right. Let's say it's a matter of policy. ...We have that... facility supervision guideline, ... And the HMIS mentioned in the guideline is [still] paper-based.... Now with the introduction of electronic*

> *systems that system has not yet been changed. Now, because the guideline requires the facility manager to produce the HMIS books, they will tell their employees that you fill in the books, but also fill in the [digital] system. Because these books will be reviewed [during supervision] but not the [digital] system…. Nowadays, e.g. for GoT-HoMIS once the patient is registered, seen by clinician, got the required medicine, all HMIS data is available in that system but the existing guideline requires the clinician to fill in the books. Now that is something that needs a change in the guideline so that it can differentiate health facilities [using digital systems]. They are treated the same when the reality of the ground is already different." (IDI 13_national level, Study IV)*

This quote underlines the cross-cutting nature of digitalization and the subsequent need to review the effects of existing guidelines on digitalization or digital systems.

Although another manager commented on the issue of data security and the lack of policy regarding the individualized data produced by electronic medical record systems, most national managers who participated in Study IV agreed that the important legal framework was in place or at least in the making (as for a policy on data security).

Finally, although most national managers from Study IV liked DHIS-2 for its numeric data, one participant, who was interested in more qualitative data for quality improvement at facility level, described it as an outdated system that needed to be replaced… Still, he pinned his hopes on real-time, qualitative, and quantitative data in the GoT-HoMIS system, in line with other participants (Study IV).

> *"…I feel we need a better system in capturing data and doing analysis both for quantitative and qualitative [data]. Something we don't have, and to be honest I am one of the people who don't really believe in DHIS-2. And I don't think it helps us as much as we think. In addition, it is an old system: That is, you started in the 1990's. Now we are talking: How much you have been updated until today. This to become user friendly, it's another question and to be sincere I am the one who says we need to find another Ford [the car brand. He was comparing data systems to cars earlier, saying that old and new cars are not the same] not this one." (IDI 12_national level, Study IV)*

5.6.2 Contextual challenges led to discretionary policy interpretation at subnational level.

As described in Study IV, although subnational managers acknowledged existing policies, they battled with implementation in terms of the discretion in interpretation they often had to use. Subnational participants mentioned the barriers they had to overcome to implement data systems and digitalization as envisioned by the national level, including i) lack of funding and infrastructure, ii) lack of technical assistance for trouble shooting at their level, and iii) related to the funding issue, a lack of integrated guidance on supervision, with the effect that supervision for data quality assurance was not carried out as frequently as they wished (Study IV).

5.6.3 Donor organizations contributed to discretionary policy interpretation.

International donor organizations were said to be supporting the government by means of i) funding technology development and piloting, II) agenda setting, iii) policy implementation at subnational level, e.g. by financing printing of HMIS registers and iv) providing technical advice (Study IV). However, national managers also described donors' involvement in the creation of data silos for vertical projects and how some of their measures at facility level created incentives for data cooking (Study IV).

> *"…We have seen some challenge with stakeholders who say: "if you test you will receive money for all clients tested positive…That's why we had doubts that it is possible that they [health care providers] cooked the data. They [donors] say they are giving it as an incentive. But it can create temptation for our people. If they see that here I would have twenty positives, I could get something. But now I only have ten, I don't know what to do so that I can add ten. Instead of getting the ones that are real, you find that maybe they want to make up the others. That case happened in region x if I'm not mistaken." (IDI 10_national level, Study IV)*

This quote illustrates how some donor organizations acted independently, despite directives from the government, but rather in accordance with the goals set by their organization.

5.7 Domain 7 – Continuous embedding and adaptation over time

The scope for adaptation of SPT technology itself was limited, but there was leeway for adaptation of the overall SPT system to better align with the values and norms of different actor groups.

Socio-culturally rooted perceptions of health care providers with regards to data appropriation and the value assigned to numeric data was not amenable by technology and system adaptation.

5.7.1 SPT tool adaptation could not solve critical disparities between health care providers' perceptions on their professional work and the value they assigned to routine health data collection.

Results from Study I suggest that health care providers were able to integrate new technology into their work if they saw it would benefit areas of their professional life that were important to them, e.g. i) workload, ii) time with clients, iii) quality of service provision. On the other hand, results from Study III suggest that the numeric data itself, also collected by SPT, may not be as important to health care providers for their perceived core work. This implies that, for health care providers, SPT's main benefit was to free-up time for core tasks and not necessarily to support routine health data collection. As a result, the motivation for adaptation of SPT to improve the latter was limited.

5.7.2 SPT tool adaptation could not address contextual barriers to its adoption.

The implementation failure of SPT described in Studies I and II provides an illustration of limitations to technology integration caused by contextual factors. Although district managers could have supported health care providers in a better way through supervision and possibly through creative solutions concerning the transport of forms, they had limited influence on funding availability for both. Results from Study IV highlight other potential contextual risks for sustainable implementation and adaptation of SPT and other digital systems. These are for example i) continued appropriation and interpretation of data and technology and ii) health care managers' perception of digitalization as main mitigation measure for contextual effects on data quality. As previously mentioned, national managers also had difficulty buying into SPT scale-up due to low fit with their vision of data sovereignty.

> *"SPT is a good thing I saw it, it is very good. But it needs some discussion so we can understand. Because I asked who owns the system and can we completely handover the system to the government? That is, you provide the social code and everything. Because now the government wants to own*

> *these things to complete them themselves. Where is the server? If we can transfer [everything], it is very good." (IDI 10_national level, Study IV)*

Although the technology itself was perceived as easy to apply, the overall SPT system posed several barriers to its institutionalization through access limitations but also the question of ownership as described above. The above quote may also underline that the value proposition in terms of output was already achieved according to national managers, despite data quality issues described under Study I and II, and that a completely different set of values was more important here.

Another example of the limited scope for adaptation of technology to overcome contextual barriers was the lack of improvements in data use. As outlined in Study I, III and IV, health care providers' lack of analytical and statistical skills was possibly more important for this than data availability in itself. However, the design of the ONGEZA project did not include an intervention to improve these skills.

5.7.3 Established communication platforms for HMIS governance did not include institutionalized reflective processes but were rather designed for downstream feedback for trouble shooting.

Study IV results describe several platforms where intended and unexpected outputs and outcomes could have been discussed within the HMIS in Tanzania, including i) annual data review meetings, ii) WhatsApp groups at various health system levels and iii) supervisory visits to health facilities by managers from different levels of the line of command. However, findings suggest that these spaces were mostly used for trouble shooting and mainly addressed data quality issues.

Study IV however captured one approach to data synthesis and use that may serve as an example for i) actor involvement, ii) approaches to data quality, iii) accountability and iv) adaptation through an intentional reflective process: *Maternal and Perinatal Death Surveillance and Response* (MPDSR) governed by the Ministry of Health. The approach of this internationally recommended strategy in Tanzania relied on triangulation of different data sources, i.e. i) DHIS-2, ii) immediate reporting of non-communicable diseases and iii) narrative data from death reviews at facility, council and national level. In addition, national managers together with experts from professional associations of obstetrics and nursing reviewed sample cases of maternal and perinatal deaths together with the facility in question as well as district and regional teams during regular zoom meetings. Initially, national managers had determined the schedule and content of these calls but had later incorporated feedback from subnational and facility teams regarding usefulness and approach, which led to a co-designed timetable allowing for adequate preparation time.

> *"We wanted to get their feedback, so we developed some data collection tools… So, we got that feedback, we had a meeting again, we did it via Zoom. And then they also helped us to improve on this process this year… So, we got feedback from the majority of the teams that felt like this was an important improvement process. And they requested some areas for improvement. And some of the teams were quite uncomfortable, they felt like it was sort of an inquiry… After we analyzed and we are still of course analyzing, but preliminary, there are some of the issues which we had to improve. One of them was ensuring that we have the teams which are reviewing to understand that this is the review, it is not an inquiry. And then also we improved the way we communicate with the teams…" (IDI 10_national level, Study IV)*

This use of qualitative AND quantitative data for service quality improvements following a death audit may also support the data needs of health care providers reported in Study III and how these could be incorporated in policy.

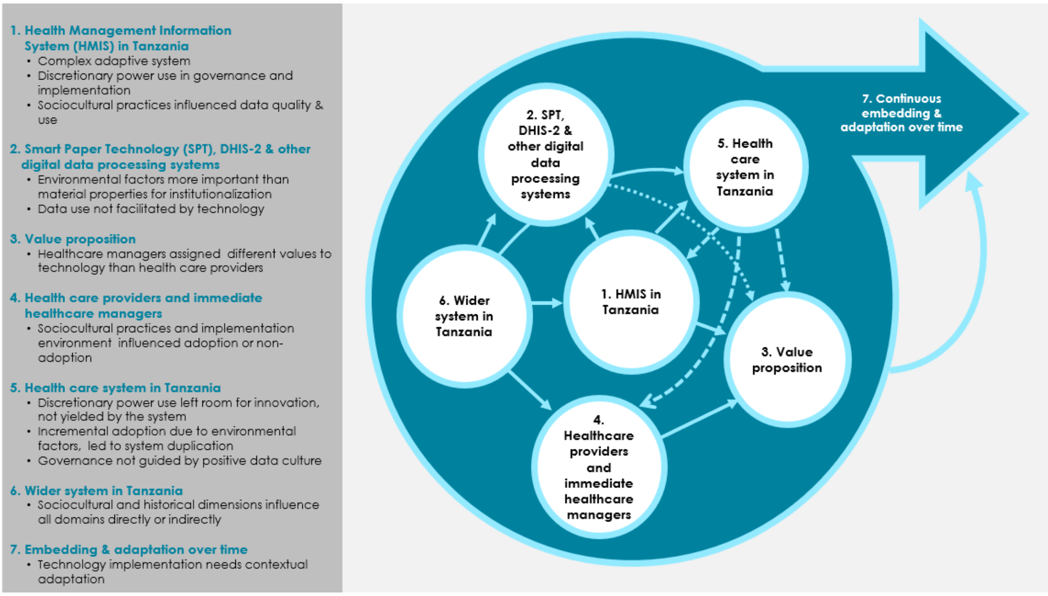
6 Discussion

6.1 Introduction

This thesis was designed to understand the social practices involved in generating and processing routine maternal and newborn health data using paper-based and digital tools within the health management information systems in Tanzania. The framework for studying *non-adoption and technology abandonment and challenges to scale-up, spread and sustainability* (NASSS), conceived by Greenhalgh et al. (95) was used to describe and synthesize the results of the four studies constituting this thesis. In this section, key findings are discussed within the thesis' results framework.

6.2 Summary of results and results framework

The collection and processing of routine health data is a complex system, closely interconnected with the overall health system in Tanzania. Governance and implementation of the health management information system is underpinned by unpredictability and uncertainty often leading to discretionary power use. The four studies constituting this thesis illustrate how diverging tacit or explicit norms, needs and agendas, related to data, influence the value propositions of different actor groups and ultimately adoption or non-adoption of data systems and digitalization efforts. Health care managers at national level mainly needed numeric data for performance monitoring and for politicians' use. Subnational-level and facility managers used different data sources: Numeric data for reporting upstream and contextual data to make sense of facility data and for local decision-making during planning. In contrast, health care providers, the primary data collectors, preferred narrative data sources to reflect their social function as professional providers of health care, but they also appropriated numeric data for this purpose, including newly introduced digital technology that had the official purpose of improving numeric data quality. The health management information system in Tanzania thus lacks a cohesive set of values, acceptable to all actor groups, to guide interactions and decisions at different system levels. While study results describe limitations to the scope of digital technology adaptation, they emphasize the importance of reflexive evaluation and adaptation of digital technology implementation to contextual information and evolving changes (Figure 20).



1. Health Management Information System (HMIS) in Tanzania
- Complex adaptive system
- Discretionary power use in governance and implementation
- Sociocultural practices influenced data quality & use

2. Smart Paper Technology (SPT), DHIS-2 & other digital data processing systems
- Environmental factors more important than material properties for institutionalization
- Data use not facilitated by technology

3. Value proposition
- Healthcare managers assigned different values to technology than health care providers

4. Health care providers and immediate healthcare managers
- Sociocultural practices and implementation environment influenced adoption or non-adoption

5. Health care system in Tanzania
- Discretionary power use left room for innovation, not yielded by the system
- Incremental adoption due to environmental factors, led to system duplication
- Governance not guided by positive data culture

6. Wider system in Tanzania
- Sociocultural and historical dimensions influence all domains directly or indirectly

7. Embedding & adaptation over time
- Technology implementation needs contextual adaptation

Figure 20 Thesis results framework

6.2.1 Social practices regarding routine data collection and processing reflected the complexity of health information system governance and implementation.

The four studies contributing to this thesis illustrate the interrelatedness and interdependence of health information systems and the overall health system in line with the attributes of complex adaptive systems (100). Routine health data documented service provision: When services could not be provided, either due to logistic difficulties, lack of supplies, knowledge or skills (15), they were either not documented (42) or numbers were inserted arbitrarily (58, 59) as reflected by qualitative and quantitative results from Study I, II and III.

Digital system roll-out was non-linear and influenced by the availability of funding. Consequently, several data processing systems often existed concurrently until a new system could be introduced as replacement, as described in Study I, II and III. This in turn increased complexity through duplicate data entry (Study II), but also policymaking, which either lagged behind progress, or preempted digital development, putting implementation pressure on the system (Study IV). Complex adaptive systems may remain static for some time and then change rapidly or incrementally (100). This emergent progress facilitated the use of discretionary power and positional knowledge as a response even at national level, a finding also described in the context of policymaking in Niger (166) and for decision-making on COVID-19 mitigation strategies in Tanzania (126).

The thesis results describe the iterative approach taken for the roll-out of digitalization in Tanzania. National managers had a vision of how the system should eventually be designed, but they also realized that their goals might be elusive due to contextual constraints. They therefore seized available opportunities, e.g. cooperation with fiber network companies to improve digital access in rural areas or step-wise technology development, whenever funding was available. At subnational level, managers continuously applied incremental changes, e.g. buying local server space whenever funds were available, or by step-wise adaptation, e.g. moving from data completeness assessment (monthly reports) to consistency (health care providers bringing register books to compare with reports). This was possible through the leeway for discretion they had, based on their in-depth contextual knowledge, compared to national-level managers.

Health care providers were service providers and data collectors at the same time, managed by the custodians and users of the data they produced, who were simultaneously responsible for commodity management and other logistics surrounding health care, data collection and processing (167). Managers' and health care providers' performance, as well as that of the health system was thus reflected in routine health data (Study I and III). This underscores i) the interwovenness of the data itself with the people who generated it and those facilitating the context of data collection, and ii) the non-linearity of this process against a background of unpredictable resource availability. The complex role of those in charge of health facilities or departments and partly of district managers at the interface of both systems shows how porous boundaries can influence and complicate allegiances within a system. Although these actor groups were formally managers, their lived experience regarding the constraints of data collection within the context of health care often adversely shaped their managerial actions, e.g. complacency with regard to retrospectively filled partographs for the sake of data completeness.

Thesis results depict how complex adaptive systems, and their self-organization are driven by human interactions in line with the findings of other researchers (99, 111, 167). For the Tanzanian health information system, these interactions were influenced by i) different perceptions on the meaning of data itself, its quality and use, ii) resource allocation and iii) actors' use of power and agency. The thesis results emphasize the importance of human interaction within power relationships for sense-making as well as the collective or individual action surrounding the implementation of data systems and digitalization (125, 126): Discretionary power practices sometimes led to unpredicted or unintended outcomes, e.g. parallel documentation systems (122, 168, 169), an emphasis of data completeness over consistency (42) or flexible use of data sovereignty at different health system levels. All these in turn influenced SPT data quality as described in Study II.

Acknowledging the complexity of the health information system in Tanzania and its interconnectedness with the overall health system is a first step in addressing systemic constraints to data quality, use and digitalization.

6.2.2 Data was appropriated through social interaction and for social purposes.

The thesis results illustrate how actors used data from routine health data sources in unpredictable ways to safeguard social relationships and mitigate contextual challenges to these relationships. Data collection, processing and use usually takes place in a specific context (Study I and III) and a political context that is framed by national and international power use, as well as by allegiances and agenda setting of different stakeholders (9, 170) as described in Study II and IV for the Tanzanian context. It is also important to acknowledge the importance of the human-data interaction and its consequences for the effectiveness of the format of data collection itself: A change from paper to digital formats, to address technical challenges, e.g. calculation and translation errors, does not necessarily change human interaction with the primary data or data use, and consequently overall system performance (Study I). These reflections are in line with Lupton who argues that "*digital technology tends to replicate social norms, relations and identities*" (171). Ziebland et al.'s results from their literature review relate to this thesis' findings on how the use of digital technology can lead to unintended outcomes related to the appropriation of the technology by different user groups, to adapt it to their lived experiences (122).

It is thus warranted to discuss findings in view of the meaning that different actor groups assign to data, data quality, data systems and technology, to better understand their motivation and to unravel implicit rules that may drive actions and reactions towards HMIS implementation (100, 111). Findings from Study I and IV indicate that health care managers were short of solutions to health care providers' lack of capacity to produce adequate data quality, despite their crucial role as primary data collectors. Study I and III shed light on health care providers' motivations and views on data and data systems as well as on the importance they assign to routine health data collection.

Health care providers identified themselves primarily with their role as care givers (172, 173) rather than with the task of data collection. They often described the latter as being undertaken for others, higher up in the hierarchy. Lower-level managers acknowledged these perceptions. This finding has been equally reported from various other settings (174).

A study from Sweden described the difficulties professional health care managers experienced in managing physicians and the degree of autonomy they had to afford to them (175). The latter reportedly left them with managerial strategies, such as negotiation instead of instruction, that weakened their own position (175). Findings from Study IV suggest that HMIS managers felt comfortable applying negotiation in their work with health care providers, possibly because they valued the autonomy clinical care providers had within the medical paradigm from their own experience. In contrast to Swedish health care managers, most of their Tanzanian colleagues had a clinical background themselves. This could also be a reason why they described positive engagement with data or data systems as an extra effort, requiring self-motivation, reflecting these managers' own transition from a clinical to a managerial role.

Findings from Study I and III illustrate how data from various documentation sources, regardless of the format (HMIS, SPT, narrative parallel documentation), was appropriated to maintain a professional image of health care providers delivering care according to standards in spite of a resource-deprived working environment. Strong's as well as Mehlberg's et al. findings confirm these results for the use of the partograph but also for other documents (59, 68).

Health care provision and documentation in rural areas of Tanzania often takes place in a challenging working environment (176) as reported by Study I and III. Previous research describes health care providers' feelings of inadequacy and dissatisfaction when facing systemic challenges to service provision, colliding with their professional values and standards of care (68, 172, 173, 177). Unpredictability of resource availability, patient behavior and outcomes are described as further stressors to health care providers (178) in line with Study I and III results. It is of note that whilst two studies evaluating SPT implementation in outpatient vaccination services in The Gambia and Uganda concur that its data quality was similar to HMIS data (136, 137), the thesis results do not come to the same conclusion (Study II). This may support the argument that the context of implementation may matter more than the technology itself.

I would argue that routine health data reflects the major challenges for good quality health care provision in Tanzania. Although health care providers are only partly accountable, they often suffer the consequences for their work and relationship with their community as illustrated by the thesis results. Based on this reflection, I would reason that health care providers may continue appropriating data to maintain their professional identities for social purposes regardless of the data collection system used, as long as their working conditions remain unchanged. Health care providers saw value in using SPT and made innovative attempts to put the system to work. However, since the context of health care and its documentation did not change, they used SPT for their own purposes described above. These findings are in line with Gilson et al.'s recommendation to align resources to policy aims to influence frontline workers' values and motivators (169).

Health care providers attempted to maintain working relationships with those in charge of departments or facilities and managers at subnational and national level, by producing a complete data set for them (58, 59) which was often flawed by inconsistencies as findings from Study II and III illustrate. The thesis findings and a substantial body of evidence from other studies underline the notion that numeric data is neither impartial nor does it necessarily depict "reality" (5, 8, 59, 68). Wendland and Hoeyer et al. describe how contextual information can be lost through datafication of events surrounding care provision (5, 10). Ruckenstein et al coined the term "*datafication*" as the quantification of qualitative information related to different areas of life (179). Health care and public health events are increasingly subjected to datafication in an effort to create accountability (10). While datafication is not necessarily a "bad thing", it can forgo information on context and lead to unintended consequences (10). Wendland and Hoeyer et al. argue that datafication can make numeric data appear objective and clean, seemingly facilitating comparison of situations that are not equivalent and thus not comparable, as Wendland puts it (5, 10). One example of datafication and how it fails to provide information about the service quality associated with birth is the international indicator regarding skilled birth attendance, which is based on the assumption that the presence of skilled personnel and an enabling environment contribute to a decrease in maternal mortality. The indicator fails, nonetheless, to capture service quality, how skilled the attendant actually is, and other contextual details related to childbirth (180).

Results from Study III suggest that health care providers felt alienated by the numeric HMIS data, because what they needed for their social purposes was dense narrative information, rather than numbers (47). The latter were valuable to create a picture of good performance, but not a useful representation of their clinical care efforts. This may be one reason why health care providers reportedly collected data only for someone else. i.e. their superiors up to national level (Study I, III and IV). In addition, their immediate superiors, e.g. shift supervisors, normalized data falsification by asking for partographs to be completed retrospectively, a finding confirmed by other research (58, 59, 177). This may have also influenced the value health care providers assigned to routine health data. Lower-level managers at facility level also appropriated data by using the retrospectively completed partographs to demonstrate the completeness of reporting by their facilities.

In Study IV national managers reported a preference for numeric data for forecasting and planning, which also satisfied the needs of national managers' main data recipients, politicians. This type of data may have also been easier to verify in its aggregated form by national-level managers, who were not as conversant with local settings as subnational managers and had no access to the primary data. Numeric aggregated data may also have been easier to interpret for the purposes of policymaking, i.e. decision-making (5, 10). However, interestingly, some managers at national level, e.g. those working on *Maternal and Perinatal Death Surveillance and Response* (MPDSR), also craved contextual information and reflected on how to better include this in their monitoring (Study IV). In fact, their described data needs were quite similar to those illustrated for health care providers in Study III.

In contrast to other research, postulating distrust in data quality leading to decreased data use (26), the managers from both national and subnational level interviewed for Study IV were comfortable with the quality of data produced and with using it, despite knowing that it did not always reflect reality. This confidence reportedly stemmed from the processes they had designed to control data. However, it may also have stemmed from their own perception about what data quality is, what level of it is needed to make decisions and their use of contextual data. Interestingly, although they did not initially volunteer this information, possibly due to the political preference for numeric data, interviews often later revealed their concurrent use of contextual information.

In contrast, subnational managers described using narrative and positional knowledge to make local planning decisions. These experiences may have had a bearing on the meaning they assigned to numeric data. Low use of routine health data at subnational and facility level is documented in the literature, and it is reported that these managers often prefer other information for their decision-making (12, 15, 49, 53). Hoeyer et al. describe how datafication can unintendedly weaken information (181) and subnational managers may have seen this effect when comparing numeric data during planning with the contextual information they had about the circumstances of data collection and the burden of disease.

In summary, managers also used contextual qualitative data to make sense of numeric data. This may have assisted them in comfortably using routine health data in line with national and international requirements, despite challenges with data quality. However, highly processed data, like maternal mortality indicators may not allow this contextual triangulation anymore and its importance may be forgotten in the international discourse about indicator monitoring to improve health service provision (5, 10).

Finally, the idea, and fear for that matter, of control through numbers has been described by various researchers (5, 8, 174) and is also demonstrated in the findings from Study I, III and IV. In the context of this thesis, the evasion of control through surveillance may also be related to the lived experience of generations of Tanzanians under colonial rule, where being counted in registers meant being visible to the colonial administration, as claimed by Pallaver (182). Rudinow Sætnan et al. argue that “a society and the statistics that count it are mutually constructed” (8). I hypothesize that apart from cultural also historical collective identity forms part of a society’s discourse surrounding data and data management systems.

The thesis results suggest that there is common acceptance among all actor groups within the Tanzanian health information system of the need for digitalization. However, as described above, actors’ perceptions, behaviors, and human interactions with newly introduced digital technology can not necessarily be predicted, because they are not introduced into a social void. Acknowledging the social dimensions of data and related practices can assist stakeholders in finding common ground, jointly creating a set of organizational values that guide interaction and decision-making in the complex health management information system.

6.2.3 Social norms and practices to connect governance and implementation around data processing were not shared between actor groups.

Our findings suggest that the health system in Tanzania lacks an organizational set of values, often termed *data culture* or *information culture*, that aligns policymaking with implementation (27, 70). The concepts of different actor groups regarding data quality and use, and the assigned importance to data collection were often conflicting.

Plsek et al. describe how actors within complex adaptive systems interrelate with and react to events according to inherent rules, that may be explicit or implicit and may also change over time (100) akin to the notion of a *data use culture* put forward by Arenth et al. and others (27, 183).

Most concepts of *data* or *information culture*, however, are reductionist, assuming that i) health management information systems are closed systems, ii) processes within the system are linear with data use resulting from data quality and iii) "evidence" for decision-making is based on numeric data. Our results suggest that organizational culture(s) around data, its quality and use and accountability for these processes is much more multilayered and interconnected, and includes decision-making based on other ways of creating evidence.

Aqil et al. see *information culture* as part of other organizational factors that determine health information system processes and ultimately performance. They also hypothesize that "*promoting a data culture will improve HIS performance*" (70) in a linear way. Responsibility for the promotion of this organizational culture is ascribed to senior managers. This conceptualization suggests that *information culture* can or must be created and that the goal is performance oriented, i.e. good data quality and use (70).

Arenth et al. describe *data use culture* as "*customs, dispositions, and behaviors of a particular group or organization to support and encourage the use of evidence, including facts, figures, and statistics, to inform their decision-making*" (27). The authors assume that improved data quality is reached through improved data production processes, which will inevitably lead to increased data use followed by the "emergence" of *data use culture* (13, 26). This implies that *data culture* materializes once the right conditions are put in place, and without a pre-existing discourse around the meaning of data and data use.

However, in line with Rudinow Sætnan et al. and others, the thesis results illustrate that data management systems and the data they produce reflect the "*social act of counting*" based on a society's social and cultural discourse (8, 10, 171). Given the multidimensionality of this perspective, I suggest that the term "*data culture*" is too broad and "*data use culture*" too narrow to describe the phenomenon of an organizational culture around data and data systems. The term "information culture" as used by Curry et al. may be more appropriate as it i) refers to information management and inclusive participation, ii) includes health care providers and management and iii) incorporates aspects of motivation and support (183). Still, considering the health information system as a complex adaptive system, I would argue that any of the terms above is too prescriptive. A set of organizational values, akin to Plsek et al.'s "*set of minimum specifications*" (100), that delineates an organizations social norms and limitation of mandates, may be a much more useful framework to guide system learning through reflexive evaluation for adaptation and self-organization under an organizational culture (98, 101).

I conclude that every health information system is based on an organizational culture in which norms around data, data use and information are embedded, but do not necessarily lead to the desired outcome. This argument entails that there may be positive and negative aspects of a prevailing data culture depending on the outcome. In addition, I suggest that if an organization decides to steer an existing data culture in a different direction there must be consensus on the desired outcome or goal. Therefore, designing a different data culture must be participatory (183). Concepts developed by and for one actor group only, may not be in line with other groups' motivators, as suggested in our results and by other researchers (99, 100, 111). Our findings suggest that incorporating the needs of the following two groups may be especially important: i) Health care providers as primary data collectors who perceive themselves as disempowered and seemingly lack self-motivation, and ii) those in charge of facilities/departments and district managers for their potential "wrecking power" and as positive or negative role models (128, 169).

What might a participatory process look like for the health information system in Tanzania? I have identified three different (explicit or tacit) goals for the three main actor groups from the four studies (and there may be many more given the indistinct delimitations of this complex system, e.g. the recipients of health services): i) Using data for change, ii) making the system work, and iii) maintaining professionalism in a difficult working environment. The thesis results further suggest that, after deriving a common goal from these, an honest debate would be needed, incorporating all actor groups. about the prevailing organizational culture and how it influences a merged goal positively or negatively. The findings of this thesis may assist this process. As a next step, I suggest clarifying which dimensions of data culture should be included to achieve the agreed goal. Aqil et al., for example, suggest the following dimensions of data culture, but these may not necessarily be relevant for the specific context: "i) *Data quality, ii) data use, iii) evidence-based decision-making, iv) problem solving, iv) bottom-up feedback, v) feeling responsible, and vi) empowerment and accountability*" (70). Arenth et al. propose the following dimensions: "i) *Awareness of need for data use, ii) access to needed information, iii) motivation to act after data analysis, iii) empowerment to act, and iv) that skills and knowledge for data use are in place*" (27). The thesis findings suggest the inclusion of dimensions like i) managerial accountability for an enabling environment for service provision and data collection, ii) health care providers' awareness of the importance of good-quality information for their professional role, iii) awareness of different information needs of various actors, iv) capacity of managers and health care providers for data analysis and use and v) data sovereignty, among others.

In addition, a discussion is needed on i) what constitutes "evidence", "data quality" and "data use" for all actor groups, ii) which benefits different actor groups hope to reap from digitalization and whether these are realistic, iii) which aspects of data and system appropriation may be harmful for goal achievement or actor groups and iv) what factors attract different actors' agency for buy-in (111). Lastly all actors need to agree on ways to follow-up on adaptation over time since information culture in constantly evolving complex systems arguably needs to be observed and adapted if it doesn't fit anymore (100) In line with Lippeveld, I would also claim that this endeavor requires stamina since it includes change for all actor groups and will probably take many years (69).

Finally, our results illustrate how information culture itself could constitute an important aspect in the organizational domain of the NASSS framework (95), when applied to health information systems. I have also previously argued that the historical context of a setting could and should be taken into account to understand contextual influences on data systems, especially regarding information culture. To my understanding, this aspect is not yet explicitly covered by the NASSS.

6.2.4 Actors appropriated digital data systems and assigned agency to them for different purposes.

The thesis findings depict the hopes and expectations of health care providers and their managers related to the digitalization of routine health data collection and processing. Health care providers envisioned a reduced workload and protection against complaints and litigation through better archiving. Health care managers hoped for better data quality and use and system integration.

The challenges described in the thesis results regarding data quality and use are in line with the literature describing the health management information system in Tanzania and similar settings and therefore digitalization may appear as the primary solution given its potential through automatization (29, 30, 32, 184). However, Greenhalgh et al. emphasize that digital systems will always need humans to do the clinical work that routine health data documents, and enter this primary data into a software, with leeway for manipulation (102). In line with this, Lupton argues that digital technologies are manifestations of social relationships and cultural concepts and thus reflect inherent practices and their assigned meaning (171). Different actor groups assigned agency to data systems, including DHIS-2 and SPT, often to fill a void left by contextual health system challenges: Health care providers described how SPT substituted managerial supervision and supported their professionalism (Study I). Health care managers in turn attributed electronic patient records and the SPT system with the ability to continuously monitor health care providers' doings (Study I and IV). In addition, health care managers assigned digital technology in general the role of a behavioral change agent that had the power to "do away" with health care providers' "unwanted" behavior related to data quality (Study IV). Further, full digitalization with its delivery of real-time data, paired with an assumed technology saviorism of future generations of health care providers were perceived as the game changer for accountability and agency in the health care system. removing the need for managerial intervention (Study IV). However, a fully digitalized system, where primary data can be seen at the national level, would potentially also create a new role for subnational managers and possibly new interactions between the different levels. How these might look may be difficult to predict and possible adaptation processes would need to be observed closely (99, 122).

Critical perspectives on digitalization and datafication further evoke the political power that is assigned to data and consequently data management systems, through its alleged i) neutrality, ii) importance for decision-making and iii) utility for accountability through performance monitoring (5, 10, 171, 179, 185). The thesis results underscore these findings: Managers interviewed for Study I and IV described how digital technology would assist them to "know" when health care providers did not perform well or cheated. Digitalization, in our case through SPT and electronic medical records, was thus seen as a means to facilitate surveillance. Results from Study III in turn describe how health care providers would evade this control by falsifying primary data.

Based on the thesis results I would also argue that neither the appropriation of data or data systems nor the value assigned to numeric or contextual data can be counteracted by technology and system adaptation. This may further underline the importance of aligning technology and implementation to the underlying norms and values of different actor groups. This will assist them to find common ground for sense-making and collective action within the system (99).

Finally, I conclude with Rudinow Sætnan et al. (8) that, despite the social dimensions inherent in numeric data we should by no means stop collecting routine health data nor constructing health indicators to monitor improvements in survival and service delivery.

We should rather acknowledge their reflection of social interaction, discourse and sense-making against the background of human suffering and the collective aim to alleviate this. This recognition will assist societies and governments to explicitly speak about the power of data and their meaning, to reveal shortcomings in health care provision and governance.

6.3 Methodological considerations

In this section, I reflect on the strengths, limitations and applicability of the methods used, including my own positionality, which are not mentioned in the constituent articles.

6.3.1 Reflexivity

Reflexivity can be defined as an iterative and conscious process to support researchers' individual and cooperative appraisal of how their subjective experiences, background and preconceptions interact with context and the research process (186, 187). Reflexivity has not only informed my choices for the theoretical underpinning of this thesis and facilitated a critical retrospective appraisal of my chosen methods but has also assisted me to position my individual story within my research (188).

I became very interested in positionality when reflecting on my standpoint towards Global Health, as a white woman, born, raised and educated as a medical doctor in Germany, one of the former colonizing nations of the African Continent and Tanzania in particular. On the other hand, my biography includes living for over 10 years in Tanzania and speaking fluent Kiswahili. I also have longstanding working experience in remote areas of southern Tanzania, from hospital to dispensary level. My work as an obstetrician, and later as the project manager of a maternal and newborn care improvement programme for the German Development Cooperation, has also influenced this thesis.

I asked myself how the privileges stemming from my birthplace and education and the collective memory of German society informs my attitude towards my colleagues, superiors and participants of this research and how they, in turn, might perceive me. I contemplated how my positionality, incorporating experiences from two cultures, could make me more prone to bias or less in the context of this research. I agree with Bukamal and Corbin Dwyer that we can be both insiders and outsiders in our research (188, 189). Bukamal writes that the intersectionality of aspects within our biography contributes to that "insider-outsider ambivalence" related to our own view of ourselves, research participants' views on who we are and our actual positionality (188). My personal conclusion regarding my positionality in this thesis' research was that of a dynamic insider-outsider status, depending on who I spoke to, about which topic and where that conversation, or observation for that matter, took place. I would therefore argue that an actual positionality does not exist since it is composed from so many angles and at so many levels and is by nature changing.

6.3.2 The use of theory and frameworks

Using theory-informed conceptual frameworks was important to develop and justify research design and methods and to understand and explain results (190). The process of identifying appropriate theoretical foundations and deciding on the conceptual framework for this thesis has helped me to locate my research within a specific paradigm and to make strategic choices on the grand and mid-level theories I wanted to use. I have based my definitions on theories, frameworks and models from the work of Nilsen (94) as outlined in the methods section and I found his taxonomy to be very applicable to the facilitation of my thought processes.

My education and the scientific literature related to my topic and research question influenced the choice of theoretical underpinning for this thesis and reflects a Western European worldview. However, I acknowledge that there may be other, more contextual, indigenous theories from within an Afrocentric paradigm (191, 192). My reading and discussions with fellow researchers on the importance of context and end-user perspectives and decoloniality informed my reflexivity about analysis and interpretation. Therefore, where applicable, I deliberately chose analytic methods or theories that explicitly included the researcher as an instrument and recognized the openness and subjectivity of interpretation (193, 194).

The field of Global Health, where my thesis is located, emerged from the disciplines of "Tropical Medicine", Public Health and International Health" (195). In this tradition, Global Health assumed a primarily positivist or post-positivist lens, i.e. acknowledging that cause and effect are probabilistic (108). Post-positivism is based on logic and empirical inquiry, theory, rigor, generalizability, and sequential steps in research design. However, this stance also subscribes to the view that there is not "one reality" (108). Still, social constructivism embraces complexity, the importance of interaction, contextuality and "the inductive development of theory or patterns of meaning" (108). In light of my research aim, I would argue that a post-positivist paradigm would be too reductionist to capture the complex nature of Tanzania's health management information system.

I am confident that the two grand theories chosen for this thesis, social constructivism and complexity theory, are applicable to the context of this thesis due to their level of abstraction. Both theories partly resonate with the afro-centric concept of *Ubuntuism*, emphasizing the "individual as part of a community, the environment, humanity and spirituality" and the reciprocity of human relationships (191, 196). Social constructivism emphasizes the construction of knowledge through interaction and lived experience, with opportunities for describing and better understanding indigenous ontology and epistemologies (192) and underlines the importance of historical and cultural norms in the process of sense making (108). Complexity theory acknowledges the interwovenness of people with their environment and each other, as the basis for a system's capacity of self-organization and adoption (100).

Sociocultural and historic realities in Tanzania could differ from the mid-level theories chosen, relating to power practices, leadership and collective action (192). Although *Normalization Process Theory* has been applied in research surrounding the integration of new digital technology into health care settings, no such study has as yet been conducted in Tanzania or similar settings. *Street-level Bureaucracy* has been applied in Tanzania and similar settings by researchers from the respective countries (125, 128, 169), with findings comparable to those of this thesis, which may support its use for this thesis. *Ubuntuism* shares some aspects with both, NPT and *Street-level Bureaucracy*. While NPT emphasizes individual coherence and engagement it also underlines the importance of collective action and social processes that "normalize" innovation (116, 197). *Ubuntuism* emphasizes the principles of "*preference of human life over commodities" and "people-centered leadership*" (191, 196). This is reflected in Study IV findings on managers' empathy for health care providers' situation, despite issues with their data collection and data quality.

Normalization Process Theory was developed as an implementation theory to increase knowledge on how new technology is "*normalized*" into existing work routines and how this leads to sustained institutionalization (118). Greenhalgh et al. propose the use of NPT for several NASSS domains (96). The theory's stipulated individual and collective processes of i) sense making, ii) decisions on participation, iii) action and iii) collective monitoring were reflected well by Study I results. While health care providers passed through the first three processes, healthcare managers did not progress beyond the second one. Their conscious or unconscious decision not to provide an enabling frame for SPT implementation led to the system's non-adoption.

NPT has assisted me in gaining insights into the potential complexity of introducing new processes in the tight workflow of health care settings. Its use for the Study I topic guide design produced interesting information that inspired the design of Study III and my thoughts about health care providers' actual data use. In retrospect, I can confirm the theory's applicability for monitoring implementation of complex interventions and their adaptation.

Several studies have hinted at the potential for unintended consequences of discretionary policy implementation in health care (121, 126-128), which would be relevant for intervention adaptation over time and for monitoring self-organization of complex adaptive systems (100). Lipsky's *Street-level Bureaucracy Theory* reflects these findings. Although power practices influencing the implementation of (digital) technology are not explicitly mentioned in the NASSS framework (apart from potential "wrecking power" of opponents of the technology) (95, 96), they are inherently tied to organizational and societal factors (123, 162) and power relationships and practices could be an important addition to the framework's domains. Retrospectively, I found the inclusion of power practices in this thesis, using the theory of *Street-level Bureaucracy*, to be very important from a system-thinking point of view (123).

The *Non-adoption, Abandonment and Challenges to Scale-up, Spread and Sustainability of Technology-supported Change Efforts in Health and Social Care* (NASSS) framework was designed based on research and implementation results. These results stipulated that a relevant number of digitalization projects in the health sector do not pass on from proof-of-concept- projects to scale-up (92, 104, 198-200). The NASSS, used as a conceptual framework for this thesis, has reflected most of the challenges for the HMIS well, except for the complexities created by power practices, especially discretionary power, and pre-existing organizational culture, as suggested in the discussion. One major strength of the NASSS framework, as compared to the PRISM and similar logic frameworks, is its emphasis on non-linearity. The seven domains and the associated list of questions to evaluate complexity are more detailed and include the wider context and adaptation over time, which may change the interaction between domains. However, the original framework suggests that unidirectional influences exist between i) condition, ii) technology, iii) adopter system and value proposition, which then influences the organization (Figure 7) and I consider this to be a limitation. In the adaptation of the framework for this thesis' results framework, it is proposed that the interconnectedness of complexity between domains be illustrated with reciprocal arrows (Figure 20). This would better reflect the social dimensions and practices that influence all domains and their interplay surrounding the routine health data system and its digitalization in Tanzania.

The *Performance of Routine Health Information System Management* (PRISM) framework, applied in Study I, was used as a process model to depict the determinants and processes involved in HMIS (94). The framework aims to quantify aspects of RHIS processes and performance to improve regular evaluation of these systems. Its use in Study I has helped my understanding of the processes involved and of possible determinants when I started this thesis. However, retrospectively, I realize that the model's reductionist stance impedes capturing the complexity of the health management information system in Tanzania. It is based on a positivist paradigm, which stipulates that health information system performance unfolds in a linear way, from determinants, via processes, to data/health system performance. The model also makes unidirectional assumptions about the relationship between determinants and processes, implying that determinants influence processes but not vice versa and that determinants do not influence each other.

This fails to capture the environment's complexity and the non-linearity of interactions and decisions which are at play in the case of Tanzania's health management information system (99).

6.3.3 Using mixed methods

Evidence from implementation science on complex adaptive systems and health information systems suggests the application of mixed methods to adequately consider contextual impact on implementation and outcome (92, 99, 141, 142, 201-203). The thesis aim requires the use of qualitative methods to understand the social dimensions and practices involved in generating and processing routine health data in Tanzania. he Given Tanzania's drive towards digitalization of health information systems, evaluating a newly introduced digital technology, like SPT, provided the opportunity to illustrate implications regarding workflow, effects on patient care and data quality. These aspects are best captured by both quantitative and qualitative methods where one triangulates the other, providing opportunities for discovery of i) unexpected negative consequences of technology introduction, i.e. on patient safety or clinical care work, and ii) innovation (143). Quantitative results from Study I and II contributed to an understanding of the different perspectives on data quality in general, in terms of feasibility and usability of digital systems. Study II provides an example of how quantitative research contributes to an otherwise qualitative research aim in a mixed methods design. An a priori hypothesis was not formulated for this quantitative study and there was no single general explanation for the results (143). Rather, results were interpreted with a contextual lens, by triangulation with qualitative findings from the thesis. Study II findings therefore illustrate the importance of contextual information for interpretation of quantitative results in implementation research on digitalization of the health sector (92, 141, 203, 204).

I would locate the methodological approach used in this thesis between a fixed and emergent design (143). The design of Study I and II was determined at the beginning of the thesis work, but results from these studies influenced the design of Study III and IV, because they generated open questions that could not be answered fully based on results and the available literature. Consequently, a multiphase design emerged, based on the design prototypes developed by Creswell et al. (143), including a convergent parallel design for Study I, which then informed sequential design for Study III and IV will in parallel, Study II was designed as a follow-up study to Study I (Figure 21).

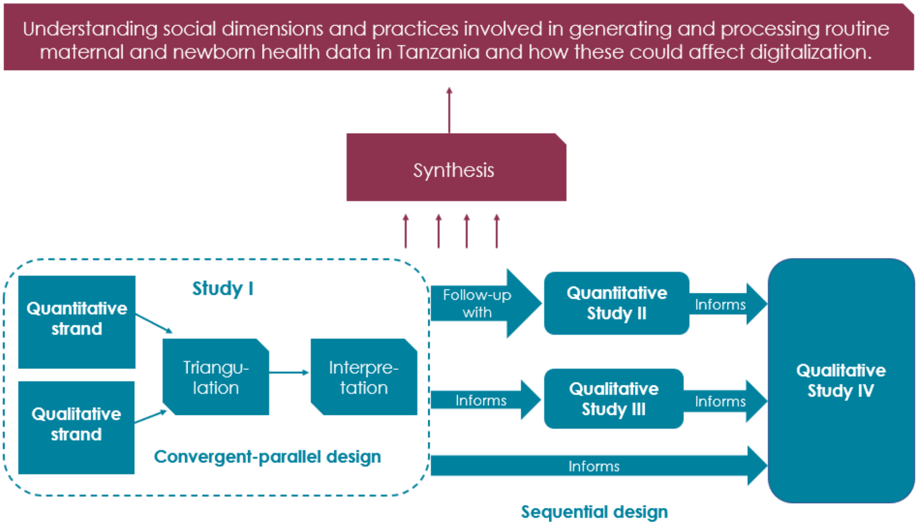


Figure 21 The emergent multi-method design used for the thesis

This iterative approach facilitated theory development and the inclusion of earlier results into later study designs.

6.3.4 Applying reflexive thematic analysis

Reflexive Thematic Analysis (TA), developed by Braun and Clarke, emphasizes the researchers' role and their reflexivity in the analysis process and the notion that codes with shared meaning and subsequent themes are developed by a researcher instead of passively "emerging" (163). TA is not bound to a particular theoretical underpinning. I found that my long-standing engagement with the South of Tanzania and my experience of health care provision and its documentation could influence my analysis in unintended ways. Therefore, having a guided but flexible pathway of continuous reflection on my experiences during the research process was very attractive at the design stage of study I and IV and turned out to be very helpful during analysis.

Retrospectively, I realize that for Study I, the emphasis on an initial codebook may resemble framework TA (205). This codebook was based on independent inductive coding of four transcripts, which we later aligned to the PRISM framework and NPT. I now see this approach as an opportunity to discuss coding with the senior researcher who coded with me, and to become more confident about my own coding. At that stage of my education in qualitative research, I believe this was helpful, although not aligned with the intentions by Braun and Clarke when formulating reflexive TA (163). I developed more independence during the analysis and through reflexive sessions with a supervisor. This assisted me, at the later stages of analysis, in identifying clusters of shared meaning that went beyond the framework we had initially applied.

For Study IV, the reflexive process with different members of the multi-disciplinary ALERT team as peer check was again very helpful to me. Based on my previous experience, I deliberately performed double coding of a few transcripts with a senior Tanzanian qualitative researcher. This was to include a diversity of views from different positionalities, rather than to reach consensus or to establish a codebook. Although double coding is not seen by Braun and Clarke as a part of reflexive TA, they mention it as a means by which to look at the data in different ways (152, 163). I still consider this to be a special kind of peer check, which was most helpful for my analysis and reflexivity, especially since we both knew the whole data set from data collection, field notes and transcription. Peer check facilitated identification of clusters of shared meaning from the data. Returning to the data at various stages of theme development and refinement, as described by Braun and Clarke (152), ensured a data-driven analysis.

I also appreciate Braun and Clarke's concept of saturation monitoring as a means to subjectively determine the point at which the information is sufficient to generate codes and themes and develop an appropriate synthesis (150). I have always been dissatisfied with the notion of "information redundancy" (206), because it stipulates that there is an objective number of interviews at which saturation is reached, instead of acknowledging that this may be different for individual researchers, research aims and contextual factors. The concept of information power embraces this individuality (149).

6.3.5 Study I: The use of time-motion methods

Most of the strengths and limitations of the time-motion methodology approach have been described in Article I. According to Zheng et al., time-motion studies (TMS) quantify "*time expenditure*" of clinical staff related to the introduction of new digital technology (207). The authors emphasize that although qualitative studies have demonstrated that the introduction of digital technology in health care causes disruptions in workflow, decreased user satisfaction and task efficiency, it has little influence on clinical care (207). The thesis results suggest the opposite. In the qualitative research, health care providers, the frontline users of SPT, were satisfied with the technology and described workflow improvements with a perceived increase of time spent on other tasks., Furthermore, quantitative data showed an increased in time taken for patient care (Study I). Zheng at al argue that the outcome measure "*aggregated clinician time*", often used in TMS, may be an oversimplification of the influence of new technology on overall workflow and results from Study I point in a similar direction. Although the use of NPT for this study sheds light on workflow amendments, I argue that a methodology that captured changes in workflow and disruption or facilitation of work processes by SPT could have yielded important information on potential for workflow improvement, buffer time and possibly harm (208). Harm could arise when providers omit work processes important to safeguard patients or data quality due to difficulties with the new technology. Results from Study III also suggest that generally, the overall workflow of documentation and clinical care could be improved in included facilities. Since one goal of digitalization described by participants of Study IV was to decrease workload for health care providers, a method that evaluated workflow and disruption of processes, rather than time spent on tasks alone, could contribute to a better understanding of how to achieve further efficiency. NPT could then support t understanding the "why" and "how" of e.g. disruptions. Zheng et al. propose two new analytical methods for TMS that may be promising in this regard: i) Work fragmentation assessment and ii) Work pattern recognition (207). The former uses "*average continuous time*" spent on a specific task as the outcome, to quantify workflow disruptions associated with increased cognitive load which according to research can lead to increased errors (156, 209). Work pattern recognition applies two modelling techniques for analysis to identify tasks frequently re-occurring sequentially and probabilities of transition between paired tasks (207).

6.3.6 Study II: Using the WHO data quality review toolkit

In my opinion, use of a universally adopted framework for data quality review, with defined dimensions, metrics and indicators, like the WHO DQR toolkit, is the greatest strength of this study. In addition, the tool kit has previously been applied to SPT (136) and to HMIS/DIHS-2 in Tanzania and similar settings (29, 30). In their review of data quality assessment methods, Chen et al. noted a variety of relevant approaches (38). During my literature review I identified several approaches to the quality assessment for HMIS, with different definitions of quality dimensions but only the WHO DQR toolkit applied in more than one study (29, 30, 136).

However, it must be noted that the WHO DQR toolkit was originally designed for data quality monitoring of a particular HMIS system in one setting over time, with the district as the smallest unit. Furthermore, a typical district in Tanzania often comprises 30 to 40 health facilities (75), as opposed to the 13 facilities as in our study. Other researchers have reported sample sizes of up 115 health facilities (30), but often facility numbers are not reported since the unit of measurement is a district (29).

We had initially aimed to include all 30 health facilities that were trained on SPT. Research restrictions during COVID-19 slowed down the training roll-out so that the last cohort of facilities was only trained in July 2020. Since the WHO toolkit evaluates indicator trends over time and we wanted to capture annual fluctuations in service coverage, we could only include those 13 health facilities that had applied SPT for one year. This rendered a statistical power calculation futile.

Additionally, the WHO toolkit, when applied to continuous monitoring of HMIS, compares all data sources, i.e. facility-based registers, tally sheets, monthly summary reports and DHIS-2 (154). Routine health data systems are complex, especially when they are partly paper-based as in Tanzania, It is necessary to include all of these when aiming to evaluate performance improvement. In contrast, For SPT we chose to compare only with DHIS-2, the final data product used for policy- and decision-making. The rationale for this choice was that we wanted to evaluate data quality of the new SPT, using DHIS-2 as benchmark. We focused on those aspects of the WHO toolkit that allowed a comparison between DHIS-2 data and SPT and added indicators for data quality specific to the SPT system but not applicable for DHIS-2, e.g. the use of the unique identifier or the timely availability of forms for scanning.

One study on the use of SPT for vaccination services in The Gambia used HMIS data from the year before SPT introduction as benchmark, because the policymakers agreed to sole use of SPT after its introduction (137, 210). For the ONGEZA study, we failed to secure agreement by Tanzanian policymakers on using SPT alone for the period of data collection. Results from Study I and IV reflect the potential negative impact of duplicate data entry and indicate reasons why subnational and national managers did not support the system beyond the proof-of-concept study despite general interest at national level. Results for the thesis, together with findings from a mixed-methods evaluation of the applicability of SPT for outpatient vaccination services in Uganda, underline the strength and importance of mixed-methods use for the evaluation of digital systems to support routine health data collection and processing (137).

6.3.7 Study III: The use of constructivist grounded theory versus reflexive thematic analysis

Reflexive thematic analysis was used for the qualitative strand of Study I with the aim of understanding aspects of acceptability, feasibility and usability of the SPT system. During analysis, clusters of shared meaning also were identified that did not directly relate to this aim but rather provided insights into health care providers' general perceptions of data and about their role in data collection. A review of the scientific literature provided similar results on i) how health care providers alter data and ii) how they perceive documentation of health care provision as a burden or as secondary to patient care (58, 59, 68). I could not identify a satisfactory theory on why health care providers would develop these practices and perceptions. Participants from Study I did not provide reasons beyond lack of knowledge and skills and lack of human resources, and this is in line with what I used to hear during my previous work, when posing the question to health care providers and managers (194). The use of constructivist grounded theory, developed by Charmaz (158, 211), for Study III provided an opportunity to generate a theory about practices related to data use and health care documentation, in line with the overall thesis aim.

It appealed to me that constructivist grounded theory includes the researchers' perspective, like reflexive TA does, but with the explicit aim of theory development (211). I also benefited from the process of memo-writing as a reflexive tool, which is encouraged by Charmaz (211). I prefer constructivist grounded theory to the original grounded theory developed by Glaser and Strauss (212), because the former is more flexible, less process-driven but more content-oriented and embraces complexity (108).

When applied to methods, the primary focus of grounded theory is often placed on cumulative interviews (108). In contrast, the methodology for Study III was embedded in the co-design approach used in the ALERT project, with i) interviews, ii) a follow-up focus group discussion and iii) observations for triangulation. I think that the use of co-design enriched understanding of the processes around documentation through its participatory and solution-based approach. By using pictorial data journeys, it became clear that health care providers have different needs than their managers with regard to data sources for clinical use or quality improvement at departmental level. Triangulation with observational data helped my reflexive process and furthered ideas about why health care providers would say one thing and do another.

Finally, the theory on health care providers' data appropriation for safeguarding social relationships that was developed in Study III using grounded theory, aligns well with the complexity of routine health data collection and processing in Tanzania. It may add another dimension to the set of questions evaluating complexity for the seven domains, as put forward by Greenhalgh et al (95). When revisiting the data from Study I for the synthesis of this thesis, I realized that the theory about data appropriation to maintain social relationships developed in Study III also applied to the implementation of SPT, which may give this theory further credibility.

7 Implications for policy, practice and research

7.1 Policy and Practice

The social practices surrounding data and statistical processes need to be acknowledged by designers and implementers of health management information systems. Numeric data is not inherently neutral. Policymakers should consider this aspect during interpretation, synthesis and use of numeric health indicators. In addition, they would need to acknowledge qualitative, contextual information as valuable evidence for decision-making at all health system levels.

Equally, policymakers, system designers and implementers need to recognize health management information systems as complex adaptive systems and therefore acknowledge the importance of i) reflexive evaluation of adaptive efforts, ii) the promotion, documentation and communication of innovative adoption and iii) the need to strengthen mid- and lower-level managerial capacity to support an enabling environment for routine health data collection and to serve as role models.

Policymakers and implementers need to be aware of the interplay of socio-cultural factors, processes and technology as well as the need to follow-up on how this affects implementation of system processes or the introduction of new technologies.

It is important to identify the existing organizational culture surrounding data, statistics and data processes in order to understand how it impacts implementation. A set of guiding values, co-created by all actor groups, can make the tacit discourse about data visible. It may also mitigate harmful norms and practices that increase system complexity and cause unintended consequences.

7.2 Research

This thesis studied the social practices of health care providers and managers at subnational and national level. Although clinicians and nurses in charge of smaller facilities or hospital departments were only marginally involved in focus group discussions for study I, they were eventually identified as gatekeepers who can serve as direct role models, with the ability to positively influence an enabling information or data use culture. The thesis' results also suggest that these gatekeepers have more opportunities to facilitate reflexive evaluation of adaptation and identify beneficial, innovative approaches to data management at facility level. Further research can yield a better understanding about how the social practices and norms of these clinicians and nurses may influence their role within a well performing health management information system.

In addition, well-designed implementation research on how best to integrate the collection of qualitative contextual data into routine health data systems could support the design of an inclusive and efficient Tanzanian health management information system. A case study on the country's MPDSR system may yield knowledge about the types of contextual data and data sources that are considered useful and how these may be integrated into health information systems to ensure their continuous use.

8 Conclusions

Responses of adoption or abandonment to digital technology were influenced to a considerable extent by social practices at all levels of the health system. Technology adoption or abandonment were linked to the actors' perceived benefits of maintaining existing social practices. These practices, which are a part of an organization's culture related to data and data processes, require attention during conceptualization and implementation of health information systems.

The context of routine health data systems is important, especially actors' reciprocal and relational transactions to negotiate benefits, cooperation and institutionalization. These contextual factors affect digital technology integration and have a bearing on data quality and use of digital and paper-based health management information systems. Context may even be more important than the format and technology of data collection and processing.

Numeric and contextual information is used concomitantly at various levels of Tanzania's health management information system. While health care providers preferred narrative information, subnational-level managers used both data types and most national-level managers favored the use of numeric data.

The health management information system in Tanzania forms a complex adaptive system with inherently high levels of unpredictability, non-linearity, self-organization and adaptation over time. Health care managers' power practices in conceptualization and implementation of policies reflect this complexity.

Digitalization of the health management information system may interact in various, unpredictable ways with contextual factors. This may introduce more complexity to an already intricate implementation environment as described by health care managers.

People and their perspectives on data and data systems are an important component in the adaptation, appropriation or abandonment of new technologies to support routine data processing in Tanzania.

9 Acknowledgements

An African proverb says, "*It takes a village to raise a child*”. So many people have helped me raise this “child”! Thank you so much for all the encouragement, support, comfort, practical help, and love!!

I would like to thank all the participants of the four studies and the two implementation science projects of ONGEZA and ALERT for their trust and openness. I will do everything I can to ensure your engagement is worthwhile.

My deepest gratitude goes out to my supervisors. Claudia Helle, Fatuma, and Atsumi, you inspired me in so many different ways. You are amazing women!

Helle, thank you so much for all your support, for cheering me up and lifting me up, when I was down. I am forever grateful for that! Your pragmatic approach to so many things that looked complicated to me has taught me a lesson. I loved our data analysis sessions, when you successfully made sense of my ramblings and formulated so well what I could not say! Thank you for Inviting us into your home, I have fond memories of your barbecues and dinners with interesting guests!

Claudia, I am grateful to you for giving me this incredible opportunity! I learned so many things from working with you. Your incredible writing skills are unmatched, and you helped me growing in this. I am thankful that I could contribute to two very different projects and work in all the areas they comprised. You gave me the opportunity to experience all this, and I will never forget this. Nor the many fun days we had together in your little house in Vermdö, the joint cooking and gardening in the incredible Swedish nature. Thank you!

Fatuma, thank you for letting me sit with you and learn from you. I really appreciated your openness to share your knowledge and teach me so many things about how to gauge and manage stakeholders regarding a difficult topic like health management information systems.

Atsumi, I don’t know what I would have done without you! You were so patient and showed so much empathy until I got my head around my quantitative data. I know the pandemic has hit you hard, but you never gave up on me!

Prof. Pembe, my “undercover supervisor”, you always made time for me and your comments on the manuscripts were just great! I really appreciate your help and engagement with designing study 4, your suggestions on how to handle high-level managers were invaluable! It still beats me how you manage all the different commitments you have, always polite and engaging.

Ulrika, time was not on our side, but you introduced me to qualitative research when supervising me for study 1. I really enjoyed your way of coding, phrasing, and re-phrasing them. Thank you!

Terry, thank you so much for agreeing to be my mentor. I guess you knew what you were up to!

Kristi, I am so grateful that you agreed to chair my defence. Your warmth, communication skills, and understanding just made you the ideal candidate for me. I will never forget our mushroom hunt in the beautiful woods near your home!

My appreciation goes to all my colleagues at Ifakara Health Institute! You made me feel so welcome and at home: Dr. Honorati Massanja, Dr. Sally Mtenga, Gumi Abdallah, Yusuf Kionga and all the other colleagues. Thank you for having me. A special thanks to Farida Hassan and Jitihada Baraka: You are both incredible qualitative researchers. Thank you for teaching me! My PhD squad at IHI, Donat Shamba and Josephine Shabani, hang in, you got this!!! Elibariki, scientist, philosopher, and life coach, thank you for all your advice and for sharing all your profound knowledge about the deep South. Aziz, I am so grateful for your support in making sense of the SPT data! Doing the time motion study with you was plain fun.

To all the colleagues from the ALERT consortium, it is such a great experience to work with people like you and you taught me so much. A special thanks to the ALERT Tanzania team, you always accommodated me and shared your experiences, Prof. Lilian Mselle, Dickson Mkoka, Beatrice Mwilike, Frank Kaduma, Prof. Hussein Kidanto, Muzdalfat Abeid, Tumbwene Mwansisya and Zamoyoni Julius. A special thanks to Fadhlun Alwy Al-beity, my sister, I am so happy that I got to know you. Doing research with you is just amazing!

To all my colleagues from the Department of Global Public Health! Thank you Marie Hasselberg and Cecilia Stålsby Lundborg for always showing interest in my studies. Thank you for the opportunity to teach in the master's student programme. I really appreciate you trusted me in that. Thanks to Viji, Véronique, Anastasia for bearing with my sometimes-odd requests and questions patiently. Tobias, Mariano, Miriam and Carina, it was always a pleasure to meet you in the kitchen and catch up!

Soha and Rosario, you are like sisters to me, I am grateful we met. I will never forget our fun dinner with "action art" at our flat in Farsta and the support you gave us, at all times. Thank you for looking at my Illustrations together my partners In "design crime"!

To my fellow PhD students at KI, past and present: Alicia, Sara, Linda, Ana, Sid, Constance, Nada, Bianca, Bérangère, Karin, Ester, Ochuwa, Funmilayo, Martina, Opeyemi, Ayobami, Mercedes, Phillip, Leo, Jay, Awale and all others in our PhD support group. Marianna, I am so happy we met at the implementation science course. I will always cherish the nice outings we had with Erik, Noor and Ayo.

I am grateful for the engagement of all my co-authors in the four manuscripts. Thank you for accepting this task and teaching me scientific writing!

I appreciate the funding of this thesis as part of the ONGEZA and ALERT research grants by Vetenskapsrådet and EU Horizon 2020.

Thank you, Michael Wells, Salla Atkins, and Stefano Bonacina for agreeing to be on my halftime board. Your comments made this thesis so much better.

Erick Msoffe, Neema Ringo, and Baltazar Ngoli, thank you for your thoughtful suggestions regarding the stakeholders of HMIS in Tanzania.

Charles Ameh and Adura Banke-Thomas, without you, my manuscript would still linger on an editor's desk at a certain journal….

I am grateful to Karima Ludin and Antke Züchner for your proofreading of this thesis. Stefanie, thank you for your incredible help with the illustrations for this thesis and for being my friend!

Stefan and Aleah, thank you so much for your friendship and for all the many cheerful occasions at your home in Karlavägen and in the summer house in Vermdö together with you and Claudia! Aleah, you are an amazing artist! I am looking forward to seeing more from you!

What would I be without all my friends who pulled me up so many times: Anjara, Artemis, Tanja, Afua, Nadine, Dani, Ann-Christine, Annette, Steina, Renate, and Cornelia: You are the best!

To the parents and teachers from LEXIS primary school in Dar es Salaam and to Magdel and Dries: You are my tribe…! Thanks to all of you for taking care of Paul!

To my larger family, Rüdiger, you are always keen on knowing where I am in my life, thank you for visiting wherever I go. To my siblings Angela and Jürgen, for being who you are. Mama and Papa, you are not here anymore, but I know you are always with me. You were often wondering what I was up to, but still you supported me. I hope I make you proud.

And finally, to the two most important people in my life: Sisty, you are my best friend and my best advisor, thank you for your wisdom and for being with me. Paul, thank you for putting up with me! I know you did not always understand, but you fearlessly went where I went. You being in this world is the best thing that ever happened to me.

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11 Appendix

11.1 Appendix 1 Popular science summary in Kiswahili

Ulimwenguni kote, wauguzi na wakunga hutoa huduma kwa wanawake wajawazito katika vituo vya afya na hukusanya takwimu za afya za kawaida. Wao hurekodi takwimu kama idadi ya akina mama wanaotafuta huduma ya uzazi kabla ya kujifungua na wanaopokea dawa kutokana na kusumbuliwa na shinikizo la damu . Takwimu hizi zinaruhusu mameneja wa huduma za afya kufanya maamuzi kuhusu idadi ya wafanyakazi na mahitaji ya vifaa/dawa na kuhakikisha usimamizi wa ufanisi wa huduma za afya.

Wakati nchi zenye kipato cha juu hutumia mifumo ya kompyuta kuingiza na kuchakata takwimu, nchi zenye rasilimali chache, kama vile Tanzania, hutumia vitabu rejesta, kuingiza takwimu za wagonjwa kwa mkono. Muhtasari wa takwimu , ambazo huhesabiwa kila siku na mwisho wa kila mwezi, kisha huingizwa kwenye programu ya kompyuta inayoitwa Mfumo wa Takwimu za Afya wa Wilaya-2 (DHS2) na mtu mwingine. Wakati wa mchakato wa ukusanyaji wa data, kuna hatari kwamba watoa huduma za afya au mameneja wa data wanaweza kufanya makosa kuhusu i) kuingiza data za wagonjwa kwenye rejesta au ii) mahesabu ya muhtasari, iii) kuingiza data kwenye mfumo wa kompyuta. Kutokuwepo kwa takwimu au makosa katika kuripoti takwimu kunapelekea kupungua kwa ubora wa takwimu. Hii inaweza ikapelekea mameneja wa huduma za afya au wanasiasa kusita kuzitumia kufanya maamuzi.

Kwa teknolojia ya kidijitali, mchakato wa kuhesabu na kuhamisha wa data hufanywa kiotomatiki na kompyuta. Data bora iliyopatikana ingeiruhusu nchi kama Tanzania kugawanya rasilimali kwa ufanisi zaidi. Mfano mmoja wa zana ya kidijitali yenye matumaini ni Teknolojia ya Karatasi janja (smart paper technology). Watoa huduma za afya hujaza fomu ya karatasi wakati mwanamke mjamzito anapohitaji huduma ya uzazi kabla ya kujifungua, anapojifungua, au anapopokea huduma baada ya kujifungua. Kila fomu ina msimbo wa mstari na nambari ya mgonjwa ya kipekee na inaweza kusomwa na mashine ya kawaida ya nakala. Takwimu hizo kisha huingizwa kiotomatiki kwenye programu ya kompyuta.

Hata hivyo, utafiti unaonyesha kwamba mazingira ambayo teknolojia ya kidijitali mpya inaletwa, yanaweza kuathiri jinsi inavyoingizwa kwa mafanikio katika mfumo uliopo. Mambo yanayoweza kuathiri hili ni i) njia ambayo watoa huduma za afya wanavyofanya kazi pamoja, ii) jinsi uongozi wa hospitali unavyohamasisha teknolojia mpya, na iii) ni sheria gani zipo kuunga mkono matumizi ya teknolojia ya dijiti.

Thesis hii ililenga kuelewa mazoea ya kijamii yanayohusika katika ukusanyaji na uchakatajii wa kawaida wa takwimu za afya za akina mama na watoto wachanga nchini Tanzania na jinsi yanavyoweza kuathiri uhamiaji kwenye dijitali. Uanzishwaji wa teknolojia ya karatasi janja na mfumo wa sasa wa uchakataji wa data ya afya ya kawaida, pamoja na vipengele vyake vya kidijiti, yalikuwa malengo la utafiti huu.

Katika **utafiti wa kwanza**, watoa huduma za afya na mameneja wa huduma za afya kutoka vituo vitatu vya afya Kusini mwa Tanzania walikuwa wameulizwa kuhusu maoni yao kuhusu teknolojia ya karatasi janja. Kiasi cha muda waliotumia kukusanya takwimu za afya za huduma za kila siku(routine) kabla na baada ya kuanzishwa kwa mfumo mpya pia kilipimwa. Hakukuwa na tofauti katika muda uliotumika kukusanya takwimu na watoa huduma za afya walitumia muda zaidi na wateja. Waliona teknolojia ya karatasi janja kuwa rahisi kutumia na inayoweza kutumika kwenye muktadha wao. Kwa upande mwingine, mameneja wa huduma za afya waliona ni vigumu kutambua faida kwa kazi zao wenyewe kutokana na teknolojia mpya. Hii ilihusishwa na matatizo ya kupata rejesta za kidijitali na majumuisho ya takwimu. Walikuwa pia na shaka kuhusu ubora wa data ya Teknolojia ya Karatasi janja. Kwa hivyo, waliendelea kuweka jitihada zao kwenye mfumo wa sasa wa usimamizi wa afya.

Utafiti wa pili ulitumia teknolojia ya karatasi janja na data ya Mfumo wa Takwimu za Afya wa Wilaya-2 kutoka kwa vituo vya afya 13 kupima vipengele vya ubora wa data kwa miezi 12, kwa lengo la kupima ikiwa data ilikuwa na ubora wa kulinganishwa. Matokeo yalionyesha kuwa ubora wa takwimu wa mfumo wa teknolojia ya karatasi janja haukuwa mzuri kwa ujumla. Teknolojia ya Karatasi Mjanja ilifanya vizuri kidogo kwa kiwango cha habari zinazopingana ndani ya data kwa ujumla (uthabiti), lakini Mfumo wa Takwimu za Afya wa Wilaya-2 ulionyesha ubora bora kwa vipengele vyote vingine, kama ukamilifu wa takwimu, upatikanaji kwa wakati na mwenendo thabiti wa takwimu kwa kipindi cha utafiti.

Utafiti wa tatu ulitumia mahojiano na watoa huduma za afya kutoka kwa wodi za uzazi katika hospitali mbili za vijijini, ufuatiliaji wa kazi zilizofanywa kwenye wodi hizo mbili, na majadiliano ya kikundi na watoa huduma za afya. Lengo lilikuwa kupata ufahamu juu ya aina za takwimu ambazo wauguzi, wakunga, na madaktari wanahitaji na jinsi wanavyoona na kutumia data kwa ujumla. Matokeo yanafafanua jinsi watoa huduma za afya walivyotumia takwimu kutoka kwenye mfumo rasmi wa kawaida wa data ya afya na vyanzo vingine vya nyaraka kudumisha mahusiano mazuri na mameneja na jamii waliyohuidumia.

Kwa **utafiti wa nne**, mameneja wa huduma za afya wanaofanya kazi katika 1) ngazi ya wizara na 2) ngazi ya mamlaka ya afya ya wilaya na mkoa nchini Tanzania walifanyiwa mahojiano ili kupata ufahamu zaidi kuhusu uzoefu wao na maoni kuhusu takwimu, mifumo ya takwimu na matumizi ya teknolojia ya kidijitali. Matokeo yanaonyesha kuwa mameneja hawa waliongoza utekelezaji kwa kutumia mamlaka waliyopewa kupitia nafasi zao (mamlaka ya kitaasisi), au kwa kufasiri sera kwa njia ambayo ilifanya hizo kuwezekana katika muktadha uliopo (mamlaka ya hiari). Matumizi ya mamlaka ya hiari yalikuwa ni kulingana na mazingira yanayobadilika bila kutabirika na rasilimali za kifedha zisizotabirika, na wafanyakazi kutokuwa na ujuzi wa kutosha kukusanya na kusindika data ya afya ya kawaida ya ubora wa wastani.

Hitimisho

Ukusanyaji na uchakataji takwimu za afya zinazohusiana na utendaji wa kila siku unafahamika kwa viwango vya juu vya kutokutabirika na kutokuwa na uhakika kutokana na mazingira magumu ambayo hufanyika. Hii inapelekea hitaji la kurekebisha mwingiliano kati ya mameneja na watoa huduma za afya na shughuli zinazohusiana na ukusanyaji wa kawaida wa takwimu za afya kwa muda kulingana na mabadiliko katika mazingira. Kwa hivyo, mazingira ya ukusanyaji na uchakataji takwimu za afya zinazohusiana na utendaji wa kila siku ni muhimu kwa kurahisisha ukusanyaji wa takwimu zinazohusiana na utendaji wa kila siku ya afya na kupata mafanikio mazuri katika kuhusisha teknolojia ya kidijitali.