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Digital Public Goods Platforms for Development: The challenge of scaling

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Abstract:
The purpose of this paper is to explore digital global public goods (DGPG) as a foundation for theorizing platforms for development. Global public goods (GPG) are widely accepted as fundamental for socio-economic development due to non-rivalry, non-exclusivity and global relevance. However, the challenges of extending the ideals of GPG to the digital platform domain are poorly understood and further theoretical developments are needed to advance our current knowledge of this relationship. To theorize the challenges, we draw on the GPG, digital platforms literature and concepts related to paradoxes. We illustrate the value of these ideas in making sense of the case study of the DHIS2 digital platform for health information primarily used in developing countries. Furthermore, the case analysis provides some practical implications on DGPG platforms.

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1. Introduction

Various discourses around digitalization emphasize the increasing centrality of information and communication technologies (ICTs) to the research and practice of ICT for development (ICT4D). The discourse of "development 2.0" refers to ICT for digital production and innovation offering the potential for grassroots development (Heeks, 2008). The discourse around "digital platforms for development", shifts the focus from standalone ICT applications to "platforms" and how these may enable a greater "level playing field" for developing countries to drive locally desired socio-economic development (Bonina, Koskinen, Eaton and Gawer, 2021; Nielsen, 2017). Complementary to this discourse is that of digital public goods, and how platforms can take on characteristics of a public good to become more scalable, enabling wider and easier access to the global development community. However, there is limited conceptual and empirical knowledge of the challenges to scaling of digital platforms in a global context, and approaches to engage with them.

Most prior research on digital platforms involves studies of commercial, for profit platforms situated in the regulative institutions of the Global North (see for example Cusomano et al 2019, Gawer & Cusumano, 2014; Ghazawneh & Henfridsson, 2013; Parker et al, 2016). The potential for translating and contextualizing digital platforms for the purpose of socio-economic development remains understudied (Nicholson et al. 2019). A key goal of this paper is to theorize the link between digital platforms and development, with a focus on health. Towards this goal, we draw on and extend a conceptual lens centered on global public goods (GPG) (Ostrom and Ostrom 1977) to further our understanding of digital global public goods (DGPG) platforms.

The relevance of GPG in development is well established in the domain of health (see for example Moon, Røttingen, & Frenk, 2017; Smith, Beaglehole, Woodward, & Drager, 2003; Smith, 2003; Smith & MacKellar, 2007; Yamey et al 2018). However, there is a paucity of literature that extends the ideals of GPG and the challenges presented by DGPG. Our point of departure for understanding DGPGs are digital technologies and content that "are freely and openly available, with minimal restrictions on how they can be distributed, adapted, and reused" (UN, 2019, p 17). In line with the call of this special issue, we focus on twin interrelated challenges: i) what is the nature of a DGPG in the context of global health; and, ii) what are the specific scaling related challenges and how can they be best addressed.

We believe such an analysis is crucial for both the research and practice of ICT4D. Conceptually understanding the nature of DGPGs and their scaling related challenges will provide rich contributions to ICT4D discourses, particularly on how the potential of technology can be better materialized for development. Theoretically, we draw on the notions of "paradoxes" for this analysis, as arguably they help to capture the dynamics of the DGPG phenomenon as they evolve over time and space. Empirically, we take the case of the DHIS2 (District Health Information Software), one of the largest and long-standing digital platforms being used for global health. As the HISP (Health Information Systems Programme) community strives to make DHIS2 take on more public good characteristics (Braa, et. al., 2004), there are significant scaling related challenges experienced, which we analyse through the lens of paradoxes.

The paper is organized as follows: in the next section, we present related literature on global public goods and digital platforms and present our conceptual framework based on the lens of paradoxes. The following section presents the methodology and case description which is

around an overview of the DHIS2. The analysis is built around the conceptual vehicle of 3 vignettes, which we analyse through the lens of paradoxes and then relate to the scaling challenge. The paper concludes with some implications for theory and practice.

2. A public goods perspective on digital platforms

In this section, we introduce the core concepts of GPG and digital platforms, from which we derive an understanding of the nature of Digital Global Public Goods (DGPG). We then introduce the notion of paradoxes to theoretically unpack the challenges of DGPG, with a focus on their scaling.

The theory of public goods originates from the economics discipline based on two foundational principles of non-rivalry and non-exclusion (Ostrom & Ostrom, 1977; Samuelson, 1954). Public goods are non-rivalrous, implying that one individual's consumption of the "good" does not influence what is available for others. They are also non-excludable, in the sense that no one can be excluded from consumption of a public good. An oft-cited example is a lighthouse, where one navigator's use of the light does not prohibit other navigators from doing the same. Many goods exhibit only one of these properties, illustrated by the tragedy of the commons (Hardin, 1968) where access to pastures are unrestricted for nomads (non-excludable) while overgrazing will lead to degradation and collapse in the ecosystem (rivalrous). In her critique of Hardin's pessimistic model, Ostrom (1990) questions the expectation of degradation and depletion of benefits when they are based on voluntary contributions. Based on several empirical examples, Ostrom shows that under certain conditions, individuals govern themselves collectively, and without market or regulation, to obtain benefits, even if the temptation to freeride is present.

In this paper, our focus is on understanding digital public goods with a global scope. DGPG in addition to being non-rivalrous and non-excludable would also be available across groups of people, social groups, geographies, and generations (Kaul, Grunberg, & Stern, 1999).

Prior research demonstrates that digital technologies do satisfy these conditions as they are reprogrammable, can easily circulate, and can perform many different functions by combining multiple forms of data. With the malleability and flexibility of digital technologies, innovation potentially becomes inclusive and accelerates further scaling (Yoo, Henfridsson, & Lyytinen, 2010).

The combination with digital technology provides characteristics to public goods that are distinctive and go beyond the popular examples of lighthouses, watchtowers, and public parks. Bonina et al. (2021) classify *digital innovation platforms* as facilitating the production of content, products or services developed by one or more parties, and to serve as the foundation upon which other external actors can effectively build further derivative and complementary innovations (see also Gawer & Cusumano, 2014; Ghazawneh & Henfridsson, 2013; Reuver, Sørensen, & Basole, 2017). There are thus strong potential network effects associated with digital technologies, which forms the core of digital platforms' rationale. For example, the Google mobile operating system 'Android' used as the operating system on smartphones such as Samsung and many others, facilitates third-party developers to build supporting applications that are distributed on App stores such as Google Play. The digital enables agility in future product development, facilitates ease of change, encourages variations, and opens the potential for new actors to participate in innovation (Boudreau 2018, Nielsen & Aanestad, 2006).

Digital innovation platform can thus be defined as structures enabling the development of multiple, different software products based on a common central framework. Such a platform architecture helps deal with complexity (Tiwana, Konsynski, & Bush, 2010) where reusable and generic functions are bundled as a platform core and specific services are developed as compliments, known as "apps" (Roland, Sanner, Sæbø, & Monteiro, 2017). Such an architecture has the potential to satisfy the technical conditions of a DGPG enabling non-rivalrous and non-excludable access. However, the market logic of deriving customer value and monetizing it, potentially distorts these DGPG characteristics with adverse implications on their scaling (Gawer & Cusumano, 2014; Ghazawneh & Henfridsson, 2013; Reuver et al., 2017). For example, Google Play operates on a market logic that emphasizes platform governance practices based on monetization, profit and shareholder value. Platform ecosystems (e.g. Jacobides et al 2018) presents "semi-regulated marketplaces" that foster entrepreneurial action under the co-ordination and direction of the platform sponsor (Wareham, Fox, & Cano Giner, 2014, p. 1211), or as "multisided markets" enabling transactions among distinct groups of users (Cennamo & Santaló, 2013). Although the platform ecosystem model offers an alternative conceptualization to arm's length market-based relationships, the emphasis on monetization of value is a barrier to the realization of the normative goals of a DGPG. This market logics focus is unsurprising given the overwhelming dominance of major commercial global platforms such as Apple, Amazon, Facebook, Google and Microsoft (Taplin, 2017). The challenge which we address in this paper is how some of the conceptual thinking around DGPGs be made relevant to the context of the public health sector of developing countries.

In table 1, we define and sum up our understanding of DGPG. First, in addition to the principles of non-rivalry and non-exclusion and being available across social groups and geographies, we posit that relevance should be of importance. Such relevance can be afforded by the adaptability offered by the digital. Furthermore, the digital characteristics of malleability, generativity and flexibility can be summed as providing positive network effects, which is especially clear for digital platforms.

Digital Global Public Goods are digital goods designed as non-rivalrous, non-excludable, locally relevant on a global scale, and displaying positive network effects.	
Digital	Adaptable, reusable, re-programmable and re-combinable
Global	Relevant locally and on a global scale
Public Goods	Non-rivalrous and non-excludable

Table 1: *A Definition of Digital Global Public Goods (DGPG)*

2.1 The scaling challenge of DGPGs: the analytical lens of paradoxes

DGPGs in the public sector of developing countries require alternative conceptualizations to that of commercial platforms in the global North because of differences in incentives, institutional context and resource constraints (Bonina et al 2021; Nielsen, 2017). The ecosystem supporting DGPG platforms across various settings is highly complex requiring technological and institutional change (Sahay, Nielsen, & Aanestad, 2019) combined with social innovations (Msiska & Nielsen, 2018). Yamey et al (2018) posit that Ebola and other recent outbreaks like Nipah in India or Zika in Latin America have renewed attention to financing and delivering "global public goods for health". Initiatives driven by global health institutions like the World Bank and World Health Organisation (WHO 2020) are also trying to promote digital means towards public goods. Furthermore, Digital Square, a marketplace

initiative in digital health, has developed a "Global Goods Guidebook" (Digital Square 2019) and a "Global Goods Maturity Model" (Digital Square 2020), reflecting the growing interests in DGPG for health which has been further catalysed by the global COVID-19 pandemic. Several open source systems have been launched to support outbreak management, such as the Surveillance Outbreak Response Management and Analysis System (SORMAS) being used in Nigeria, Ghana, Fiji and Germany. SORMAS was developed during the West African Ebola outbreak in 2014/15 as an early warning and disease management system that was migrated into an open source software application in 2016. SORMAS displays many features of a DGPG: it is free of charge, open source, independent from IT companies and interoperable with other platforms such as DHIS2.

The challenge of freeriding and the "tragedy of the commons" (Ostrom and Ostrom 1977), provides a lens to understand the different paradoxes that challenge scaling processes of these various DGPG initiatives. Paradoxes are "comprised of contradictions that persist over time, impose and reflect back on each other, and develop into seemingly irrational or absurd situations because their continuity creates situations in which options appear mutually exclusive, making choices among them difficult" (Putnam et al. 2016, p72). A contradiction represents "bipolar opposites that are mutually exclusive and interdependent such that the opposites define and potentially negate each other" (ibid). A paradox perspective highlights organizations as conflicted sites of activity containing dynamic relationships between "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith and Lewis 2011, p.386). In this paper, we aim to explore the value of the paradox lens to understand the challenges of scaling of DGPGs.

Poole and van de Ven (1989), in a seminal paper identify various conditions that contribute to paradoxes and how best they can be resolved. They identify a paradox as "concerned with tensions and oppositions between well- founded, well-reasoned, and well-supported alternative explanations of the same phenomenon" (p565). They propose a theory building approach to make sense of paradoxes around four generic ways in which two opposing theses might be related : (1) the opposites are kept separate and their contrasts appreciated; (2) paradoxes are resolved by clarifying levels of reference and the connections among them, which could be at micro or macro levels, for example a global multinational trying to relate operating standards to different local levels; (3) A third approach is around the temporal dimension, where different time periods result in paradoxes; and, (4) synthesis of a new concept or perspective. Poole and van de Ven argue that these four approaches can be used in combination to make sense of and for understanding resolution of paradoxes. For instance, an acceptance of paradox (principle 1) opens consideration of the influence of micro & macro levels and of the effects of time (principles 2 and 3) in making sense of the causes of the paradox.

In summary, Poole and van de Ven identify the following different conditions that contribute to the construction of a paradox: i) different levels – micro and macro levels; ii) different temporal dimensions; and, iii) different reference standards. Our analysis will focus on understanding what are these conditions that generate different paradoxes, how do these conditions challenge the scaling process, and how best these paradoxes can be resolved with positive implications for scaling.

3. Research approach

In this section, we present the research methods, followed by the overall case context. This provides the backdrop to discuss three case vignettes which highlight the use of the theoretical frame of paradoxes to understand the scaling challenge.

3.1 Background and case description

This research was carried out under the aegis of the global Health Information System Program (HISP), a network of North-South-South collaboration where the Department of Informatics at the University of Oslo, Norway (UiO) has a key role as platform owner. This collaboration is a movement of actors in the health informatics domain with the ambition to strengthen health information systems in developing countries (Braa & Hedberg, 2002). We base our choice of this case partly on the authors' extensive and long-term engagement with this project, which has provided for unique insights, experience and access. A key output of HISP is the DHIS2 digital platform, which is released as a free and open source artefact. Since its inception as DHIS Version 1 in the mid-nineties in South Africa, the DHIS2 has grown in stature and maturity and now represents one of the most important digital platforms globally in the health and other sectors, such as education and food security. The DHIS2 today is supported by several development partners (such as GAVI, Global Fund, UNICEF, Gates, etc.) within the framework of a public good, implying central funding to UiO for the development of the platform should lead to the benefits of the same being made available to all (currently 70+ countries use DHIS2). UiO seeks to build and release DHIS2 as a DGPG but face many practical challenges in meeting the ideals of non-rivalry and non-exclusivity, which has implications on its scaling. The aim of this case study is to unravel some of these challenges through the lens of paradoxes, and specifically focus on understanding them in the context of scaling.

3.1.1 Case context: Building and evolution of DHIS2 as a DGPG

DHIS started as a small-scale pilot in South Africa in the mid-1990s. As a fusion of participatory approaches to software development and a health management philosophy of decentralization, it was strongly inscribed with the needs of district health managers to design and manage their information system themselves (Braa and Hedberg, 2002). The adoption of DHIS grew over the years up to national coverage in South Africa and various initiatives began to adopt it in other countries by the early 2000s. To take advantage of the growing internet penetration DHIS version 2 (DHIS2) was introduced in 2006 taking the form of a web-based interface, incorporating novel functionalities based on the specific implementation needs in new countries. The Indian state of Kerala and Sierra Leone were the first implementations, and by 2010 Kenya was the first country to implement a fully online and web-based system as mobile internet was considered adequate at the district level (Manya et al, 2012).

It was, and continues to be, a digital software platform primarily to support decentralized routine health management. The functionalities support all stages of the information cycle, from data collection, through processing, to analysis and presentation. We can explain the basis of DHIS2 by an innovation platform logic (Bonina et al 2021; Cusomano et al 2019); the architecture is designed with a generic core that enables local innovation. Anyone with internet access can at any time download the most recent version of DHIS2, the source code, as well as required libraries and required third party products (such as Chrome or Firefox browsers). DHIS2 also comes with a set of bundled apps, developed by UiO or through their partners in the South (such as HISP Tanzania, an independent entity with close collaboration with UiO) available in an "app store" maintained by the platform owner. The app store is

similar in concept to Apple App Store or Google Play and some DHIS2 apps are also available on these platforms too. Thus, we posit that the digital software platform DHIS2 fits well with the two key criteria of a public good as downloading the software does not hinder or reduce the possibility for others to do so (non-rivalrous); it is not possible to prevent anyone from downloading it (non-excludable). In accordance with the criteria for a DGPG it is globally available and relevant across a wide range of user groups. The platform architecture allows local innovation as apps, increasing its potential relevance globally.

A cause and effect of the growth and global scale of DHIS2 platform is its generic nature. The process by which DHIS2 has become increasingly generic is not linear, intentional, nor has it followed a strict pattern. However, over time, functionalities, which may initially be developed to address a specific problem in a particular context, are "polished by diversity" into a generic and global version available for download (Sahay, Sæbø & Braa 2013). DHIS2 is composed of a core of generic and flexible meta-functionalities, allowing customization to varied contexts. A second dominant process is platformization (Roland et al 2017). Platformization involves the creation of a marketplace as a service and maintaining the process value through transaction facilitation, user experience, and integration. Platformization has not been an intentional strategy but grew out of efforts to respond to increases in scale and to decrease dependencies in an increasingly complex software application. At the time of writing, DHIS2 consists of a stable core, APIs, bundled apps covering most use cases and apps developed by partners and third-party developers available in the DHIS2 'app store'. The organizations in the ecosystem around DHIS2 have also grown over the same period.

Thus, DHIS2 reflects GPG principles as it is open source software available for anyone to download, implement and use. It is also a flexible platform demonstrated in the adaptation for use in other sectors than health, including education, water and sanitation, agriculture, road safety etc. Due to its openness and flexibility, it is impossible to know the exact number of DHIS2 implementations. It is known that Ministries of Health and other organizations in more than 100 developing countries use DHIS2, together covering an estimated population of 2.28 billion people (dhis2.org/in-action). In November 2020, the Ministry of Health in 73 countries (primarily developing countries) used DHIS2, out of which 60 were nationwide implementations, and 13 were in the pilot stage. In addition, 22 Indian states used DHIS2. There is also a range of other organizations using DHIS2 independently for reporting in the countries they are operating, including PEPFAR, Médecins Sans Frontières (MSF), International Medical Corps, Population Services International (PSI), and Save the Children.

The activities around DHIS2 is also reflected in the DHIS2 Academies. The Academies are a core part of the DHIS2 community and crucial to develop the national and regional capacity to successfully set up, design and maintain DHIS2. The Academies have three levels, including the Fundamentals, available online and for free; Level 1 covering the basic features of DHIS2; and Level 2 covering specialized topics, including disease surveillance, server administration, implementation strategies etc. The Academies in 2020 were primarily online, and Level 1 attracted approximately 170 participants, and Level 2 attracted 400. The digital DHIS2 annual conference attracted 940 participants globally, to share their experiences from DHIS2 implementation and together build knowledge from the various usages and settings.

As of November 2020, HISP UiO had 82 employees working with the DHIS2 software and supporting its implementation. This included 47 software developers, out of which 15 were located at UiO (the other in, e.g. Spain, Vietnam and the US). In addition, UiO had an

implementation support team of 23 (10 located at UiO) and 12 working with information and support (10 are located at UiO). UiO supports the implementation of DHIS2 in countries through a network of 10 HISP groups. HISP groups are long term and trusted UiO partners located in developing countries (currently in Vietnam, Bangladesh, India, Sri Lanka, Uganda, Tanzania, Nigeria, Togo, Rwanda, and Mozambique). HISP groups engage in DHIS2 software development, and they arrange national, regional and global capacity building activities including hosting and arranging DHIS2 Academies. They play a key role as a local capacity that can provide implementation support to Ministries of Health, health programmes and others in their country and region. Regarding funding of the team at UiO and implementation projects in countries, UiO has a range of financial partners (donors), including the University of Oslo, The Norwegian Agency for Development Cooperation (Norad), The Global Fund to Fight AIDS, Tuberculosis and Malaria, The President's Emergency Plan for AIDS Relief (PEPFAR), Bill & Melinda Gates Foundation, Center for Disease Control and Prevention (CDC), the vaccine alliance Gavi, UNICEF and the World Health Organization (WHO).

3.2 Data collection and analysis

We follow a similar approach to Roland et al. (2017) in data collection and analysis. The data collection has emerged from the authors' individual activities, analyses, collective discussions and reflections concerning DGPG and paradoxes related to DHIS2. The involvement of the authors with HISP, DHIS2, and health information systems spans contexts, processes and several decades, but only more recently has a focus emerged on DHIS2 as a DGPG.

Our case study is interpretive (Walsham, 1995, 2006) and data was collected during participant observation in processes involving activities such as software development, strategy development, international seminars, discussions at conferences, implementations in multiple countries, discussions with funders and participation or running training workshops. This broad and longitudinal participant observation across different software development processes, implementation sites and user-groups act as a background for this paper.

We base our analysis on three vignettes with associated paradoxes related to DHIS2 positioned theoretically as a DGPG, and we use these vignettes to analyze how the paradoxes relate to scaling. A vignette is as a tool to zoom in on, illustrate and examine key processes and episodes in a case study (Kotlarsky et al. 2014). They have a story-like structure with a chronological flow and are limited in time, space and the number of actors involved (Miles, Huberman and Saldana 2013). As a result of a series of intensive discussions between the authors we chose the 3 vignettes as representing revelatory cases of paradoxes in DGPG scaling emerging from a larger body of data.

The source of data for vignette 1 is mainly derived from regional meetings of monitoring and evaluation (M&E) officers in 2-3 districts in India in 2018, where two of the authors were present and engaged as participant observers. However, this vignette is positioned as an episode in a participant observation engagement that was longitudinal in nature, involving contact with the field site over a period of about 2 years and involved extensive interviewing of key participants, coupled with access to documentary evidence such as memoranda and reports. Data collection for vignette 2 is positioned in the backdrop of the authors active engagement with prioritization debates and actions in UiO. The authors are co-located with the DHIS2 development team in Oslo, participate actively in development projects and have regular daily contact as participant observers including attendance at formal (eg. DHIS2 development roadmap presentations) and informal meetings (over lunch, coffee and social

events), related presentations and events such as the DHIS2 conference when the global community of DHIS2 users are invited to Oslo. The authors also collected data on ongoing development priorities by accessing the DHIS2 discussion forum[1] and the internal DHIS2 development Slack community discussion where functionality changes are often discussed and reported. Furthermore, some of the detailed specifics that are reported in the vignette concerning the introduction of the new tool for roadmap prioritization were derived from an interview that was recorded and transcribed with one of the DHIS2 product leads. Lastly, vignette 3 is derived from the longitudinal PhD research into DHIS2 implementation conducted by Abyot Gizaw (2014) who is one of the DHIS2 core developers now based in Oslo. Abyot's PhD was supervised by one of the authors who acted as advisor, participant observer and also carried out some of the interviews with Abyot in India and Ethiopia. As well as participant observation, all three studies from which we select the vignettes used semi structured interviewing following the interpretive case studies tradition (Walsham 1995). Interviewees were asked to respond to broad questions and encouraged to offer their own world view and respond more broadly than in a structured interview. The interviews were supplemented by other data sources such as company documents, the minutes of meetings, and informal contact. A second feature of the studies from which the vignettes are derived is longitudinal research. Respective sites were visited regularly or several times over a period of years. This style of study captures the process of change over time including shifts in the action and perception of the actors.

Our vignettes are based on a storyline, a narrative development of a sequence of events, responses and interpretations through the voices of central participants. With the aim to theorize paradox in DGPG, we have used the vignettes to focus our analysis and to explore relevant dimensions of the concepts. The vignettes are thus illustrative examples used to articulate and express the paradoxes playing out in practice. The aim of the data analysis is interpretive generalization (Walsham, 1995) where we are attempting to develop concepts, apply theory and derive specific implications which may be valuable in contexts other than the particular case study.

4. Case Analysis

We present our analysis through the vehicle of 3 vignettes. These are now presented and analysed, particularly using the theory of paradoxes to understand the scaling challenge of DHIS2.

4.1 Vignette 1: The paradox of using sophisticated tools for relatively simple analysis

4.1.1 Context

Uttar Pradesh is the most populous state in India, and with 200 million inhabitants represents the most populous sub-national division in the world. Administratively, the state is divided into 75 districts and 800+ sub-district units (called Blocks) which become the focal units for the delivery of health care services to the population of the state. Given the size of the state and its historically poor health indicators, the Bill and Melinda Gates Foundation (BMGF) established a strategic alliance with the state to support health system strengthening processes, including those relating to health information systems. These efforts are being implemented through the India Health Action Trust (IHAT) established in 2003 by the University of Manitoba, Canada under a bilateral agreement of the governments of India and Canada. IHAT in turn contracted HISP India, an NGO, in 2015 to carry out various HIS strengthening activities. A central focus was on creating a statewide central portal on the DHIS2 which

[1] https://community.dhis2.org/

would host all state health related data in one database, to enable stronger analysis and use of information.

4.1.2 The vignette: the case of output related tools

The vignette concerns a visit of two Oslo researchers in 2018 to 2-3 districts to observe regional meetings of M&E officers covering 5-6 districts. The focus of these meetings was for the M&E officers to discuss their monthly health data (generated from the DHIS2) and see how it can support decision making and follow up in respective priority areas of districts. The vignette particularly focuses on the use of the Pivot Table feature of the DHIS2 for enabling user defined statistical analysis[2].

At the end of the meeting, the two Oslo researchers initiated an open discussion with the M&E officers on the various output related tools in the DHIS2, including the dashboard, analytical tools such as the pivot table, and other features for generating output reports, the ease of effective visualization, data quality tools and various others. Through the discussion, the aim was to understand how these various output related tools were relevant to the officers for their everyday use and analysis, and how could it be improved to suit their needs.

In general, the officers said the system was easy to use, but they had the following complaints:

- Generating reports was a time-consuming process due to poor internet connectivity. To get around this challenge, at the sub-district level, the staff entered data into excel sheets which was then imported into the UPMIS portal. However, this was a laborious time-consuming process, particularly because multiple facility data was being uploaded. While this uploading process helped with addressing the internet challenge, it meant the data validation functionalities available at the point of data entry in the DHIS2, could not be used.
- IHAT team took responsibility for validating data on a monthly basis by correcting data entered in the UPHMIS portal and the paper data through local validation committees. There was limited ownership of the data by the district doctors since they were not entering the data. The doctors also believed their problems were elsewhere (lack of medical staff, medicines and equipment) and not directly related to the HIS. As users were not able to provide feedback through the system or view inter-district or inter-block comparative data, their motivation levels were low.
- There were also basic problems with the data configuration in the application. For example, there were too many data elements to report on (monthly dataset was 8 pages long), even though some services relating to those elements were not provided at the facilities. Similarly, in hospitals the staff had to report data on services provided in the night, which never happened. This resulted in many blanks or zeros in the reports, which showed the facilities in a bad light. The state would have liked to include a summary of how many zeros and blanks had been filled for a month.
- There were reasonably well-established institutional processes around routine data management. Sub-district level block validation committees made monthly data quality analysis. The M&E officers had monthly review meetings with the district magistrate (civil servant who is head of district administration). For these routine processes, the M&E officers expressed the need for easy to use tools for visualization through charts and bars, and to be able to do easy export to ppt files. They also needed tools to drill down on the data to perform root cause analysis, which was currently not

[2] For more detail on pivot table in DHIS2 see https://docs.dhis2.org/2.34/en/dhis2_user_manual_en/analyze-data-in-pivot-tables.html

possible. They would also like to see more detailed error messages. For example, they would get a message that "36 data elements are ignored", but it was not clear which were those elements. They would like to see the results of a validation analysis in a summary table which gave in one place, the errors, its type, source and time period, and what was checked and what was violated. Sometimes it would seem that data is being uploaded, but the users would not get to know if the process has been completed or there has been an error.

- Given the challenges of weak internet, users stated they would also like the option to download only parts of the raw data, which was not possible. There were also issues highlighted about the layout, for example, to see other users' favorites in the dashboards, or the Apps should be more clearly visible on the screen and not be hidden in a corner.
- On the pivot tables, they believed that there were given too many options (such as on periods – daily, weekly, fortnightly etc.), while they needed just one or max two options. They also wanted easier to use information on how to populate min/max values for conducting data validation.
- They were issues in creating outputs, for example the HMIS report was only available to download in pdf, while they needed it in Excel. In creating the monthly report, they would like to just give the name of the month and not the start and end dates. They complained about the inconsistent nomenclature (such as "institutional deliveries" and "institutional deliveries new") which made it difficult to select reports. They also got confused from the point that the data list came in alphabetic order while in the report there was no data entry order followed. In the reports, with the ID for facility, they would also like to know the corresponding district and block names, which was not possible. They also would like more analytical outputs such as score cards, league tables, with more descriptive labels (not just short names). There were also challenges in printing of reports, particularly in terms of formats and completeness of printouts.

4.1.3 Analysis of vignette

The key paradox inferred from this vignette is that while the development team continued to add in their releases new features for strengthening outputs and analysis, the typical user in a district of a developing country required more basic functionalities, and the new features added on with a release, often detracted and not added to the value the users got from the software. An example was the different options of periods which the user got, which confused them as it required additional knowledge of how to navigate different options, while they wanted to work only with two periods.

The explanation of the paradox, in terms of Poole and van de Ven (1989) was the competing effects of trying to deal with the macro and micro simultaneously. At the macro level, the development team in seeking to cater to the "universe" of users, including district users, researchers, and data analytic experts in multiple country contexts. This required them to continuously add new features, often for increasingly sophisticated use. This process went counter to the needs of the micro-level of the district level users, who wanted specific and easy to use functionalities to help support their everyday use, such as of generating required reports and downloading them to ppt files. This paradoxical relationship resulted in opposing scaling effects. While making the product more comprehensive helped the scaling at the macro level (such as movement across countries and user groups), it proves detrimental for various local contexts to adopt the system, thus constraining scaling processes. Resolving this scaling paradox would require effective scaling to simultaneously take place at both the levels

of the macro and micro, with mutually synergistic effects, described by Gizaw (2014) as generative innovation.

4.2 Vignette 2: The paradox of prioritizing voices that tend to be unheard

4.2.1 Context

At its inception, DHIS2 was designed based on the needs in South Africa and progressively expanded to the context of other Low- and Middle-Income countries (LMICs). Initial software development in developing the first versions of DHIS2 (in 2006 and further to about 2012), was carried out primarily by Master and PhD students who were intimately involved in local implementations and worked with those who used the information systems. With the massive growth of DHIS2 implementations over the last one and a half decades, this in-context development style has become unfeasible. Concurrently the development process has been professionalized, with up to 50 full time developers organized in various product teams coordinated from the University of Oslo. This corresponds with growing number and heterogeneity of users and organizations and the demand for new development is far outstripping the availability of resources. It has also become much more difficult for developers, detached from sites of actual use both culturally and geographically, to assess what should be prioritized. Central to the continuous evolution of DHIS2 is the platform development roadmap, based on prioritized user requests for changes originating from different regions, specific countries and user groups. Inevitably, the core team in Oslo cannot accommodate all user requests neither can commensurate resources (i.e. developer time) be dedicated to each request. This leads to a process of prioritization, which is inherently a complex task where all cannot always be equally satisfied.

4.2.2 The vignette: roadmap prioritization initiative

The product lead of the DHIS2 Analytics team responded to the challenge of prioritizing requests in what was thought to be an objective manner by developing a roadmap prioritization matrix. Most use-cases need analytics functionality and a great variety of requests are directed towards this team. The product lead estimated that they can only accommodate about half the requests at any stage of the product development cycle. The question facing this individual is “which requests should be prioritized, coming from who, and in which release cycle?”. While the primary implementations of DHIS2 are users from governments in global South low and/or middle income countries, according to the product lead they tend not to actively voice their requests for changes in functionality. These groups are constrained by geographical distance implying the physical separation often across great distance, limited ability to meet in person and develop social relationships. By contrast, users from donor organizations and other users in the West, tend to have closer proximity and resources to visit Oslo and “make their voices heard” implying greater influence over the DHIS2 functionality. This mismatch led the product manager to develop this “objective” prioritization methodology.

Overall, the prioritization of requests for changes to functionality is applied based on four main criteria: perceived benefits of the request for different user groups, global relevance, ease of implementation and the availability of developer resources. To measure the relevance and benefits, a score calculation was introduced. The basis of the score calculation is the request’s impact classified from “very low” to “critical”. Secondly, origin of the request is classified in order of priority:

- Internal request (highest score)
- Ongoing projects (thus tied to deliverables)
- Partners

- Known users
- New users
- Unknown (such as being picked up from the public discussion forum)

The internal requests and ongoing projects request can emanate from several sources, as the core team seeks to be directly or indirectly involved in implementation projects, including those by Ministries of Health. The two axes of impact and origin provides a combined score, with a certain threshold for requests to be accepted on the DHIS2 platform roadmap. For example, a single new user will have to request something assessed as having critical impact to make it to the DHIS functionality roadmap, whereas a Ministry of Health involved in an ongoing project can request requirements assessed as having low impact but accepted on the roadmap. At least, this is the principal in theory, in practice, the process of determining potential impact of new functionality is problematic. UiO software developers are responsible for this determination of impact, using several inputs to aid them:

- First, some requests originate from the online discussion forum for DHIS2 users and it is possible to quantify impact by counting replies to a request, voting, and number of 'likes'. A forum administrator typically processes several requests and formulates these into "tickets" in the DHIS2 issue tracking system.
- Second, developers will attempt to document the reasoning behind the request. This process is facilitated by the group of experienced users that commonly make requests and have good habits of documentation. However, most users tend not to provide detailed explanation of the reasoning behind the request thus influencing the outcome.
- Third, the origin of the user making the request will influence the evaluation of impact.

A user who is well acquainted with DHIS2 will probably have good reasons for suggesting improvements, even if the full reasoning behind it is not immediately obvious to developers. This leads to a major quality difference between the requests. A company with long-term ties to the core team and much experience in using and deploying DHIS2 will provide well-articulated and well-motivated tickets, making it easier for the core team to work with the request. At the same time, description of tickets coming from the Global South users tend to be relatively skimpy on details required, and thus more difficult for the developers to work with. The Ministries of Health from LMICs are typically not directly paying for their requests to be materialized as these are met through a complex mechanism of pooled funds from donors to the Oslo core team. Consequently, their voices tend to be heard less than those directly paying for their requests.

This systematic method for ranking requests leads to a score between 0 and 1000. However, the DHIS2 product lead estimated that the scores of around half of the requests change at least once. These changes can emanate from a further round of prioritization considering the estimate of effort to implement the new functionality. For example, implementation of demanding requests depends on a very high score. Further, unimportant requests can end up in larger groups and receive a "bundled" score. This is typical for some user interface requests, which may be minor such as changes to font sizes. These would never be prioritized to the roadmap for a single user but if bundled together may be accepted onto the roadmap. Once on the roadmap, with a score from the ranking exercise, requests go through one more stage of prioritization that deals with requests with the same score. To resolve these cases the various DHIS2 product leads will meet to agree the respective priority.

Change requests are conditional on available resource which in the case of DHIS2 was initially provided by grants from the Norwegian government aid agency Norad. While this

core funding has continued, other global donors and NGOs have also joined to provide financial support. However, these users often tie their funding to deliverables of functionality serving their needs. While the functionality will be available to all, these users are in a very different position compared to Ministries of Health and health programs in developing countries without any financial resources to invest. The product lead estimates that 60-70% of requests come from HISP groups and other partners in the South, while the rest comes from International NGOs. The HISP groups typically want stable features, while the NGOs want more cutting-edge features.

4.2.3 Analysis of vignette

The paradox identified in this vignette, is that while Ministries of Health in low and/or middle-income countries are the core target group for DHIS2, given that HISP is funded by development partners (like Norad and UNICEF) primarily as a development project, they have limited influence in shaping the prioritization of the development road map. This mismatch then has implications as described in vignette 1, where increasingly sophisticated features are consistently added to the DHIS2, which may be of marginal relevance to Ministry of Health users. Various reasons contribute to this paradox. Fragmented Ministry users have weaker abilities than the macro level international NGOs to coherently voice their priorities in a way that their influence is heard and acted upon. Donor voices are supported by contractual stipulations and representatives travel to Oslo for lobbying activity leading to high levels of priority and influence in shaping the trajectory of growth of the DHIS2 platform. There are also inherent difficulties the Ministry users have in collecting and communicating their voices, arising from language, resources, which contribute to keep their voices relatively muted. While the product lead has sought to bring in a degree of objectivity to the prioritization process, the views of Ministry users may not reach this stage due to failure to document effectively for example. The rational principles underlying the prioritization matrix is inherently ill-equipped to deal with the many subjectivities involved.

This paradox is related to the macro – micro category of Poole and van de Ven (1989) which is manifested in the evolution of the DHIS2 roadmap and attempts are made to meet multiple unequal competing interests. DHIS2 scaling is taking place across geographies and domains of usage however the production process has distortions arising out of the processes of prioritization that favor the macro influence of the donors and where voices of the relatively fragmented micro level are not adequately heard. It has proven impossible to neutralize subjectivities in the implementation of the supposedly objective prioritization methodology. Similarly, on the consumption side, there are challenges of unequal infrastructure, resources and knowledge. Overall, the implications of this paradox is to constrain processes of scaling in accordance with the GDPG principles of non-rivalry and non-exclusivity.

4.3 Vignette 3: The paradox of building software simultaneously relevant for global and local contexts

4.3.1 Context

The context of this vignette is from the perspective of the global core DHIS2 software development team. This is based on the experiences of a core development team member, Abyot Asalefew Gizaw, who carried out DHIS2 application development both at the level of countries (in Ethiopia, India, and Tajikistan) and with the core development team at Oslo over the last 14 years. In his PhD thesis, Gizaw (2014) analyzed through the notion of "open generification", the paradox of making the DHIS2 simultaneously relevant both for local and global settings. This vignette is made up from two examples from his research to illustrate the paradox, one of a success and the other a failure.

4.3.2 The vignette

The development team of the DHIS2 is engaged with designing generic technology that fits into multiple contexts, trying to find a pragmatic balance between global and local settings. The premise of this development effort is that while software travels as a global actor, its use is situated in multiple local settings, characterized by their respective social, cultural, political and technical realities. The inherent challenge is how to bring these sets of processes into a virtuous cycle and generate a continuous interplay that enables global software to travel and for local use to be a success.

The first example is from India, where the HISP India team in 2007 was working for a particular State, engaged with building a dashboard based on the DHIS2. At the time, the DHIS2 was at a very nascent stage, and the concept of the dashboard did not exist. The Commissioner of Health from this state, who was a visionary and very interested in data analytics, invited the HISP India team to design dashboards. The lead developer from HISP India, literally sat in the Commissioner's office for several months, and he would be given specific instructions on what kind of visualizations were needed, going into micro details of color, location on the screen and other details. To say the dashboard was hardwired to the requirements of the State would be an understatement.

In addition, there were issues around the skill levels of the Indian developers and the quality of the software code being written. The local team had their own software code writing style, and in general, they did not practice modular and architectural design principles, as was being promoted by the global team. The limited communication between the global and Indian teams, resulted in the local team working within their own framework and practices. At a later point, the global team attempted to refactor the local dashboard solution and build a generic solution out of it but could not succeed because of the code limitations and inadequate documentation. Going through the thousands of lines of code to refactor and restructure turned out to be a frustrating encounter, which convinced the global team to abandon the local solution and develop a new dashboard solution from scratch. In conclusion, the dashboard solution while becoming very well embedded into the Indian state system, could not be disembedded from that context, rearticulated and reembedded as a global generic solution.

The other story is from Ethiopia, also around the same time as the Indian case, concerning the development of multidimensional attributes to data elements in the DHIS2. With this functionality, different categories could be assigned to data elements (such as children 0 to 5 years and 5-10 years), and respective values noted against each category. Prior to this functionality being provided, each category was treated as a separate data element. The limit of such an approach was experienced by Gizaw when he was designing the national health information system for Tajikistan. In Tajikistan, each data element had an extremely high number of categories and sub-categories, leading to the national system having more than 30,000 data elements. Catalyzed by this experience, Gizaw was driven to find an appropriate technical solution, which could then also be used for his project involving the Ethiopian Morbidity and Mortality system. This system also needed to be able to report morbidity and mortality figures by multiple categories of age and gender. Several factors contributed to the success of this functionality. One, the developer (Gizaw) had a direct field experience (in Tajikistan and Ethiopia) of the problem and the urgent need to find an appropriate technical solution. Two, subsequently Gizaw joined the global team in Oslo, and was able to interact with the global team to understand global design approaches and gradually refactor his local solutions and make it more generic and relevant for the global core. Three, Gizaw also took generification as a central problem of his PhD thesis, and thought deeply of how to address

this challenge, both conceptually and practically, which helped to design a well thought out and elegant solution. Four, the quality of the code developed in the Ethiopian case was higher than in the Indian example and was thus more easily amenable to refactoring and generification.

4.3.3 Analysis of the vignette

The fundamental paradoxes highlighted through this vignette are again related to macro – micro, that the DGPG must be relevant simultaneously for multiple local and global settings where the fundamental premises for their sustainability are opposing. For the macro (global), the software needs to be transferrable while for the micro (local), it needs to show ability to be deeply embedded and institutionalized. To be relevant locally, the code must be deeply embedded in the local context, and to be globally relevant, it should be possible to disembedd the code from the local context and to circulate across multiple settings. This requirement is inherently paradoxical. As our two case examples highlight, the ability to resolve the paradox is reliant on a number of factors – the quality of the code, the possibility of the developers to engage with both local and global conditions to understand competing requirements, and other institutional and technical conditions. At the local level, are local innovations, specific artifacts and development practices. It is normal to have multiple instances of local innovations and specific artifacts at the local level depending on the existing sociotechnical realities and situated design practices. Between the global and local, there is the need to enable continuous and cyclical interactions. Scaling involves processes of embedding, when going from the generic to multiple specifics; and disembedding, when coming back to the generic from multiple specifics. The interaction takes place in a broader contextual space characterized by work practices, organizational structures, infrastructures, standards, policies, and funding, as well as political, cultural and societal values.

5. Discussion and conclusion

The case vignettes highlight some of the challenges regarding the nature of a DGPG in the context of global health, specifically related to scaling. In various ways the vignettes explain how actors have encountered the paradoxes associated with scaling a DGPG while sustaining the key conditions of a DGPG regarding rivalry and exclusion. The paradoxes are chiefly associated with Poole and van de Ven's (1989) description of the macro and micro: in the first vignette, we encounter the paradox of the micro level user knowledge and needed functionality positioned against the necessity to scale the DGPG to serve the macro level global "universe" of users. The second vignette tells the story of the paradox related to the much greater influence of donors on the DHIS2 functionality and how the voices from users at the micro level such as individual health ministries are unheard. In the third vignette the story concerns two episodes of micro level customization for local functionality that shows differing outcomes for scaling to the macro level of the global platform. These paradoxes in various ways display the empirical challenges related to realizing the non-rivalry and non-exclusion ideals of a DGPG. In this section, we proceed to discuss two main themes: i) the relevance of DHIS2 as an exemplar DGPG ii) how paradoxes may be addressed in relation to subsidiarity and collective action. Finally, we summarize our contributions and draw implications from our research.

5.1 Is DHIS2 an exemplar DGPG?

We posit that DHIS2 is a relevant exemplar of a DGPG, implying a typical or ideal model drawing on the definition of public goods as non-rivalrous and non-excludable, in which free market forces will not efficiently produce such goods alone. Our findings concur with Ostrom and Ostrom (1977) that public goods are usually supplied by the State, or some other

collaborative network, which seeks to coordinate collective action on behalf of the public. In the case of the DHIS2 platform, the platform owners, UiO have taken this responsibility together with partners, including donors and Ministries of Health. DHIS2 illustrates the concept of DGPG building on the limited literature (Yamey et al 2018) presenting a digital format with close to zero cost of replication and an ability to re-program, combine, build upon, and share. This corresponds to the emphasis on adaptability and reusability described in a recent report commissioned by the UN Secretary-General (UN, 2019). The DHIS2 app store mirrors the success of commercial platform ecosystems such as those around iOS and Android, reaping the benefits of positive network effects (Cusomano et al 2019, Tiwana et al., 2010). However, our analysis of all 3 vignettes reveals the implications of an absence of governing market mechanism for DGPGs in a dynamic state that must be continuously monitored as non-exclusive and non-rivalrous. Our conceptualization of DGPG is thus positioned as an ideal or an accomplishment influenced by the unique characteristics of a digital innovation platform that permits changes in the platform characteristics (the core of DHIS2 and apps) over time. The key implication of this understanding is that there are mutual dependencies between the constituent parts of DGPGs. For example, the trait of being locally relevant expressed in vignette 3 is achieved by the opportunities offered by the digital nature of the public good. Positive network effects increase with adoption in a self-reinforcing cycle and the scaling towards global adoption adds contextual diversity necessary to develop for global relevance. Concomitantly there is a paradoxical effect that the platform scaling towards serving the macro level priorities will become overly generic and in the worst case scenario into a state of 'design from nowhere' (Suchman, 2002) that is prohibitively difficult to re-program, adjust, or localize thus challenging the ideals of non-exclusion and non-rivalry.

5.2 Collective action and subsidiarity

The next important area of relevance to our focus concerns collective action and subsidiarity (Olson 1989, Sandler 1998; Føllesdal 1998) and the potential of South – South community-based networks to address at least some of the paradoxes identified in the 3 vignettes. Subsidiarity concerns the allocation of authority, power and tasks in a political order and about determining at what level of government – or governance – these should reside (Føllesdal, 1998). The problems of collective action were theorized by Olson (1989) in a treatise around the mechanisms for groups of individuals to act in their common interest for the realization of public goods. Across the 3 vignettes there are various instances of paradoxes related to collective action. There is an effect that with greater scaling the collective action of various groups is diminished (such as the ministries in vignette 2). Across all 3 vignettes, the more macro interests of the donors appear incompatible with the smaller players who become increasingly marginalized. This collective action paradox plays out as dominance of the macro effect of donors vs. micro level requirements and becomes accentuated over time which eventually challenges DHIS2 status as a GDPG. The problem is not insurmountable however and subsidiarity may offer helpful mechanisms of governance. Føllesdal (1998) interprets two main subsidiarity conditions related to effectiveness and necessity: that action should be taken at the level where it is most effective and that action at the higher level should be taken when lower levels cannot achieve the set goals in isolation. This is in line with attempts at subsidiarity to promote collective action currently ongoing by UiO to build South – South community-based networks in the form of decentralization into the "Health Information System Programme (HISP) network". This has the aim of providing more opportunities for countries (e.g., Ministries of Health) to have greater influence in the global HISP-UiO centre where the development and fund allocation is carried out. In this new regional HISP strategy, the aim is to create South – South consortia of nodes and coalesce them into regional nodes directly funded by development partners (such as Global Fund)

rather than for the funds to be routed through Oslo. It is hoped that this innovation will allow the coordination between the micro level of analysis and alleviate the fragmentation described in the 3 vignettes. It is proposed that by allowing the coordination between various Ministries functionality needs and aggregation of requests from community-based groupings would lead to greater levels of local influence and lessen the problems associated with global scaling. The 'Regional Hub' is the new organizational level of the HISP network, agreed by the DHIS2 investment partners, including Global Fund to increase capacity and coordination of country-level technical assistance and other DHIS2 Implementation support across the HISP Groups within a region. HISP Hubs will be governed by an MOU (with UiO) with a defined Steering Committee and this level of subsidiarity it is hoped will lead to sustained collective action.

5.3 Conclusion

In conclusion, the paper provides two main contributions: firstly, it combines concepts related to global public goods (e.g., Ostrom and Ostrom 1977) and digital platforms (e.g., Bonina et al 2021) specific to the applications in health. The second main contribution relates to our theoretical and empirical analysis of paradoxes in GDPG. There is significant optimism regarding the potential of GDPG; for example the World Health Organisation Global Digital Health Strategy (WHO 2020) Framework for Action states : "The collaboration will include building on synergies, facilitating technical collaboration, and developing quality assured and evidence based global digital health public goods that can be shared and used globally." This statement is echoed by The UN Secretary-General's Roadmap on Digital Cooperation (UN 2019) that calls for action in the realm of "promoting digital public goods to unlock a more equitable world". The contribution of paradoxes theory to public goods illustrated with the vignettes draws attention to our conceptualisation of the ongoing accomplishment of the ideals of a DGPG.

The contribution to practice is to emphasize the potential but also the paradoxes of DGPG. The analysis draws attention towards the paradoxes that occur here in the macro – micro related elements of the theory: influence of power dynamics, knowledge, and particularities of local context vs. global relevance. Thus, our message for policymakers, consultants and other practitioners is that DGPG should be understood as an ideal, a socio-technical accomplishment that is ongoing rather than as embedded into a static portable technological artefact.

Future work would benefit from two main foci: firstly, attention to other DGPG in sectors beyond health would broaden our knowledge of the specific implications and design considerations. Secondly, research looking specifically at the supporting ecosystem building on the insights of Jacobides et al (2018) would enable in-depth analysis of the symbiosis and challenges presented by the various supporting actors and networks in a DGPG platform. Thirdly, future work could consider how social responsibility may be realized in a DGPG governance considering for example Zuboff's (2015) criticisms of the major digital platforms relating to surveillance, privacy, and security.

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