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Digital Transformation as an Enabler for Advanced Services in the Sanitation Sector

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Abstract: People in Base of the Pyramid markets still face difficulties when it comes to sanitation. Container-based Sanitation (CBS) services represent a promising advanced sanitation service. Despite the observed outcomes of CBS services, organizations face obstacles when providing these services. To overcome these obstacles, digital transformations of these services are being carried out. We rely on multiple case studies to understand these digital transformations. Our findings highlight (1) the challenges these case organizations faced before engaging in the digital transformation, (2) their individual digital transformation pathways, and (3) a general framework for digital transformations in BoP markets.

Keywords: Container-based Sanitation; advanced services; Internet of Things; Base of the Pyramid; WASH; sanitation

1. Motivation

The 4 billion people in the world who subsist on a few dollars a day are often referred to as the Base of the Pyramid (BoP) [1]. Much of the BoP population lacks access to necessary services [2,3] such as water, sanitation, and energy. Considering our empirical context of sanitation, 2.4 billion people do not have access to a toilet that is connected to a sewage system or vaults that are regularly emptied and serviced [4], 892 million of which practice open defecation [5]. In addition, the excreta of 4.5 billion people is not safely treated or disposed of properly [5]. To better serve the BoP population, organizations need to move beyond offering basic sanitation products to the BoP population.

A typical illustration of a basic sanitation product is the building of pit latrines, without concern for the wider excreta management system. While this approach can be designed to be very affordable, scalable, and even suitable for rural areas, it is not suitable for densely populated, informal, urban areas. In such conditions, basic sanitation offerings do not guarantee how and where excreta enters a sanitation system; how and for how long it is contained on site; how it is transported to a treatment facility; how it is treated; and how it is finally disposed of or re-utilized [6]. A system-perspective is critical for achieving the Sustainable Development Goals (SDGs) 6.2 "... access to adequate and equitable sanitation and hygiene for all and end open defecation" and 6.3 "... improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" [7].

Therefore, organizations should create advanced sanitation services. The idea of advanced services originates from the servitization discussion describing how product companies are increasingly transitioning from offering products to basic services, and from basic services to advanced services [8].

Advanced services are generally distinguished by their focus on outcomes and the tight links to the necessary capabilities for achieving these outcomes [8].

Container-based Sanitation (CBS) services are promising advanced services in the sanitation sector in low-income markets. CBS services mostly target individual BoP households. CBS is a sanitation system in which the toilet contains a sealable container for storing the excreta. The containers are collected frequently and transported to a treatment site. At this site, CBS organizations use various treatment methods, some of which harness the nutrients and energy contained in the excrement.

As an advanced service, CBS services enable the following important outcomes. CBS organizations try to maximize the number of people in urban areas with access to dignified sanitation in a cost-efficient manner. Households that use CBS sanitation services have been shown to feel less ashamed and safer, more modern, and prouder of their sanitation situation relative to their neighbors [9].

Since CBS services deliberately account for the whole sanitation chain, they avoid illegal or unsanitary dumping of excreta during collection and transportation. CBS services should ensure safe treatment and disposal or reuse of the material they collect. As a result, an important outcome for some CBS service providers is the contribution to the circular economy, e.g., closing resource loops and minimizing resource consumption. By achieving these outcomes, CBS services provide a robust option for safely managed sanitation.

To achieve these outcomes, CBS organizations develop capabilities starting with designing and manufacturing toilets, marketing CBS sanitation services to the BoP households, collecting the excreta and transporting them to the treatment site, treating the excreta, recovering resources from the excreta, and selling usable end-products such as compost and energy products.

Despite the demonstrated outcomes, as an advanced service, organizations struggle in providing CBS services. CBS services are complex, given the personal nature of the service and could pose a public health risk, if there were an accident. Organizations are challenged in successfully operating CBS systems and in growing (scaling) them into large-scale solutions. Digital transformations play a vital role in dealing with these challenges.

In our study, we applied a multiple case study approach investigating how five organizations utilize digital transformations in providing CBS services. The main objective of our study is understanding digital transformation as a key enabler for advanced services in the sanitation sector. This overall objective consists of three sub-goals: (i) identifying the current challenges in providing and growing CBS services, (ii) explaining how CBS organizations utilize digital transformation to tackle these challenges, and (iii) exploring a common pathway for digital transformation.

Our study makes three important contributions. First, we extend the idea of advanced services from the previous focus on companies in industrialized markets toward organizations in BoP markets. We consider organizations providing advanced services in BoP markets as an interesting "anomaly" [10] to the prevailing theoretical assumptions of companies shifting from products toward basic services, and then to advanced services. Second, in line with the recent contributions on digital technologies in low-income countries, we investigate digital transformations in the context of serving BoP markets. Third, our empirical context of sanitation services in BoP markets is important for achieving SDGs 6.2 and 6.3.

The article is structured as follows: in the next section we describe the existing theoretical perspectives on CBS services and digitalization in more detail, we explain our research method in Section Three and present the results in Section Four. The article ends with a short conclusion of the theoretical and managerial implications of the study as well as the opportunities for future research.

2. Theoretical Perspectives

2.1. Digitization and Digital Transformation

Digital transformation is a process of reinventing and re-engineering a business to digitize a company. This transformation is the deliberate and ongoing digital evolution of a company's business model, strategically, tactically, and operationally [11,12].

Digital technologies have become increasingly important in all firms for achieving competitive advantages [13]. They are embedded in the current discussion of Internet of Things (IoT) and/or the Industrial Internet, connecting the physical and digital worlds through layers of sensors and actuators, connectivity, and analytics [14]. Digitization and digital transformation are contemporary phenomena, which are explored through a rapidly growing field of research contributions. This growing number of contributions can be structured into the general discussion of the digital transformation, digitization for advanced services, and digitization in BoP markets. Space consideration permits us to discuss only the key contributions in detail, whereas Table 1 summarizes contributions in more detail.

Table 1. Summary of contributions to digital transformation and service literature.

Digital Transformation	
Bharadwaj et al. (2013) [15]	There are four key themes that guide thinking on digital business strategy: (1) the scope, (2) the scale, (3) the speed, and (4) the sources of business value creation and capture.
Matt et al. [16] (2015)	Digital transformation strategies span boundaries of corporate, operational, and functional strategies.
Mithas et al. (2013) [17]	Digital business strategy is not solely a matter of optimizing firm operations internally or of responding to one or two focal competitors, but also arises from awareness and responsiveness to the digital business competitive environment.
Nylén and Holmström (2015) [13]	Presents a framework supporting ongoing improvement in the digital innovation process: user experience, value proposition, digital evolution scanning, skills, and improvisation.
Yoo et al. (2012) [18]	Digital transformation entails three important traits: (1) the importance of digital technology platforms, (2) the emergence of distributed innovations, and (3) the prevalence of combinatorial innovation.
Digitalization for Advanced Services	
Ardolino et al. (2017) [19]	Digital technologies are linked with service transformation pathways through the identification of digital capabilities such as user identification, product identification, geo-localization for specific time and usage instances, time-stamping, intensity assessment, condition and usage monitoring, prediction, adaptive (remote) control, optimization and prescriptions, and autonomy capabilities
Cenamor et al. (2017) [20]	Adopting a platform approach for leveraging the value of digital and information technologies (e.g., smart and connected machines) for advanced service offerings enables both customization and operational efficiency. Leveraging value from information modules to facilitate the orchestrating role of back-end units and the builder role of front-end units.
Coreynen et al. (2017) [21]	Digitization options are aligned with three servitization pathways: industrial, commercial and value servitization. Industrial servitization relies on digital means such as information and communication technologies for work-flow visualization and advanced manufacturing technologies such as 3-D printing. Commercial servitization relies on digital means for customer relations management, e.g., web apps, digital "marketplaces". Value servitization is based on digital products that radically change provider-customer relations.
Lenka et al. (2017) [22]	Digitization capabilities can be viewed in terms of intelligence, connect, and analytic capabilities. Perceptive and responsive mechanisms create value through these digitization capabilities.
Opresnik and Taisch, (2015) [23]	Combining big data with servitization establishes a third layer of added value, "information", to the existing ones, product and service value.
Vendrell-Herrero et al. (2017) [24]	Digital servitization transforms the structure of supply chains, separating the infrastructure operations and service provision from production and impacting the power of firms in vertical relationships. Digital services produce a paradigm shift in consumer valuation.
Digitalization in the BoP Context	
Dey et al. (2016) [25]	Mobile phone usage as an opportunity to digitize value creation with the BoP population.
Gebauer et al. (2017) [26]	Remote monitoring is an enabler for pay-per-use services in BoP markets
Mansell (2001) [27]	Digital opportunities exist in developing countries

2.1.1. Digital Transformation

This general discussion highlights the characteristics of digital transformation such as the importance of digital technology platforms, the emergence of distributed innovations, and the prevalence of combinatorial innovation. A digital platform is a building block, providing an essential function to a technological system, that acts as a foundation upon which other firms can develop complementary products, technologies or services. The emergence of distributed innovations means that digital technologies tend to "democratize" the innovation process. They distribute the control over innovation activities across multiple organizations and move the locus of innovation activities toward the periphery of organizations. Combinatorial innovation suggests that digital artifacts are combined with existing and new modules on products or services [18]. Accordingly, digital transformation strategies span the boundaries of corporate, operational, and functional strategies [16].

Digital transformation can take the form of continuous improvements in the digital innovation processes or deliberate strategic initiatives. Continuous improvements cover key areas such as user experience, value proposition, digital evolution scanning, skills, and improvisation [13]. Strategic initiatives involve precisely defined steps of digital realities, digital ambitions, digital potentials, digital fit, and digital implementation [28].

2.1.2. Digitization for Advanced Services

Research has begun to apply digitization to the context of advanced services. Again, Table 1 summarizes the key contributions. For example, [22] argue that digitalization requires a certain set of capabilities including intelligence, connect, and analytic capabilities. Intelligence capabilities refer to enhancing functionalities through embedding smart product components as well as sensing and capturing of usage and operational data. Connect capabilities include the wireless transmission of signals and data to the cloud as well as networked functionalities through interconnected assets. Analytical capabilities are about predictive customer insights through logical data processing and value visualization through simulation of scenarios [22]. Similar studies highlight digitization capabilities such as user and product identification, geo-localization for specific time and usage instances, intensity assessment, condition and usage monitoring, etc. [19]. Research explores the alignment of these digitization capabilities with the pathways toward advanced services [21].

Altogether, these capabilities enable product companies to utilize digitization for the provision of advanced services. Most of the rapidly increasing number of studies on the digital transformation focus on industrialized markets. Less attention has been paid to the digital transformation in BoP markets.

2.1.3. Digitization in BoP Markets

It is worth noting that digital transformations differ between industrialized markets and so-called BoP markets [29–31]. Managerial, consumer and other institutional contexts vary significantly between BoP and industrialized markets. Furthermore, digital transformations in industrialized markets aim to secure future competitive advantages and are challenged by re-engineering businesses that may already be successful. In the BoP market, digital transformation is not about achieving competitive advantages and re-engineering already successful businesses. Instead, digital transformation is reported to be the actual foundation for sustaining the provision of services to BoP populations. For example, digital technologies have been reported to play a key role for sustaining the operation and growth of energy [32], financial [33], health [34], and water [35,36] services to BoP populations [37,38].

Digitization in BoP markets originates from the discussion of leapfrogging. The idea is that the BoP markets are untapped markets, which make it possible to skip-over certain established technology options in favor of implementing more modern technologies [27]. Lately, the digitization of BoP markets has played a role in the development of frugal (reverse) innovations [39].

Digital transformations in BoP markets are often associated with mobile payment systems. Mobile phones and later mobile payment systems have quickly penetrated the BoP market. Mobile phones

allow organizations to reach and serve BoP customers cost efficiently. Organizations can tie services to clients who have been identified through their mobile phone accounts, and can use the functionality of mobile payments. Mobile payments entail very low transaction costs and allow customers to pay for services in small, but frequent amounts [25]. Later, digital technologies were developed to include remote monitoring, which allows companies to connect products installed in low-income countries. Connecting these products allows organizations to monitor and control product usage, which is often the basis for pay-per-use business models. Pay-per-use business models avoid high upfront investments, which can limit the ability of BoP customers to purchase products [26].

A typical illustration of such a digital transformation is the recent rapid growth of solar home systems in BoP markets. Organizations providing solar home systems consisting of solar panels, batteries and the necessary electric devices rely on mobile payment systems for letting customers pay for electricity as it is consumed, instead of purchasing the whole system upfront. In addition, organizations utilize remote monitoring systems to track and regulate electricity consumption.

2.2. Container-Based Sanitation Services

2.2.1. CBS Services Covering the Entire Sanitation Chain

CBS systems are nothing completely new, similar "removal" or "interception" types of sanitation services have been introduced in various countries (United Kingdom, Australia, Japan, Kenya, Bolivia, and South Africa). These initiatives have often failed due to being too expensive, too difficult to supervise, being prone to supply chain disruptions, and relying on inadequate roads and infrastructure for excreta collection [40] and have largely either been abandoned or replaced with water-born sanitation [41,42].

In the early 2000s, CBS systems have been revitalized due to rapidly urbanizing areas in low-income countries, in which the building of sewers and treatment capacity has not kept pace with population growth, so new excreta management solutions are needed, particularly in light of uncertainties such as water scarcity and the local effects of climate change [43]. A new generation of CBS organizations is pioneering the CBS services. Of course, these CBS organizations face similar challenges as the earlier CBS systems, such as difficult terrain, poor roads, dispersed collection points and time-sensitive nature of collection [40]. This new generation deliberately covers and manages the entire sanitation value chain (e.g., user interface, containment, conveyance, treatment, and reuse or disposal) to achieve the expected outcomes of providing access to dignified sanitation, avoiding illegal or unsanitary dumping of excreta, and closing resource loops and minimizing resource consumption.

Importantly, this new generation has departed from the idea of CBS as a service that BoP households received from the government. Instead, these CBS organizations consider households as actual customers. These customers pay for CBS services as a subscription service, instead of using other options such as public toilets, building pit-latrines, or sharing with other households. BoP households generally have some disposable income, but they have several other non-sanitation related expenditures, so customer acquisition is a tenuous process for CBS organizations.

CBS organizations are offering services in densely populated urban and peri-urban areas where conventional sanitation systems are not realistic or feasible due to political, geographic, or financial obstacles. As pioneers, these organizations have gone beyond the pilot phase and are increasing the number of households subscribing to the CBS services. Currently, these organizations each serve 100 to over 1500 households. CBS organizations include Sanergy in Nairobi, Kenya; Sanivation in Naivasha, Kenya; x-runner in Lima, Peru; Soil in Cap-Haïtien and Port-au-Prince, Haiti; and Loowatt in Antananarivo, Madagascar. Table 2 illustrates their approaches to CBS. These approaches are very similar and entail only slight differences in a few elements in the sanitation chain.

Table 2. Activities along the Sanitation Chain for CBS organizations.

	User Interface	Containment	Conveyance	Treatment	Reuse or Disposal
LooWatt	Different models of dry toilets, some urine diverting, excreta is sealed in plastic film by the user	Excreta are sealed into plastic film via a flushing motion by the user. This sealed material sits in a barrel.	Pushcart	Anaerobic digestion, pasteurization	Biogas used in CHP generator Pasteurized digestate used by farmers, some digestate mixed with rice husks for vermicomposting
Sanergy	Various UDDT models	Excreta barrels are lined with a plastic bag	Pushcart	Compost, Anaerobic digestion, BSF	Compost sold to farmers, BSF larvae sold as feed
Sanivation	UDDT	Excreta barrels are lined with a plastic bag	Tuktuk	Solar hygenization	Hygenized fecal sludge is mixed with char-dust to for briquettes for cooking and heating
SOIL	UDDT	Unlined Barrels	Pushcart, motorcycle, transfer station, truck	Composting	Compost sold in bulk and by the bag
x-runner	UDDT	Excreta barrels are lined with a plastic bag	Truck	Composting	Compost used by gardeners and landscapers

Considering the *user interface*, except for Loowatt, all CBS organizations in this study rely on urine diverting dry toilets (UDDTs). They market the CBS services as a rental and/or subscription service to BoP households. These BoP households pay a weekly or monthly fee and CBS organizations have to collect these payments regularly. Sanergy differs slightly from that approach by also targeting local entrepreneurs. Such entrepreneurs start small sanitation businesses, in which BoP households living in the surrounding area pay a fee for using their well maintained UDDTs. As part of the *containment*, CBS organizations provide cover material (e.g., ash, sawdust, bagasse, peanut shells and other locally available material) to help with controlling odor. These organizations also have in common that generally they rely on locally available containment options. Depending on the toilet design, options include a mix of jugs, barrels, bags, buckets, and films.

Considering the *conveyance*, collection is either once or twice a week for BoP households, except for Sanergy's sanitation entrepreneurs, where collection is often daily. In the conveyance, all organizations rely on locally appropriate and available means of transportation (e.g., pushcarts, motorcycle, tuktuk etc.). The collection of excreta is complex. Collectors may need to enter customers' homes. The performance of these collection systems is sensitive to population density and size, waste volume, number of BoP households, the amount of time spent interacting with them, distance to the treatment facility and financial factors such as the price of fuel and labor [44]. While locally available means of transportation are relatively affordable, they also entail capacity constraints making it difficult to improve collection costs by growing the number of BoP customers.

Among the CBS organizations sampled, composting is the most common *treatment* option. In addition, CBS organizations have explored alternative options such as black soldier flies (BSF), anaerobic digestion, pasteurization, or solar hygenization. These treatment options enable certain *reuse* of resources and safe *disposal*. For example, CBS organizations sell protein or fertilizer to interested customers.

CBS customers demand high service quality. When CBS organizations can manage to provide a high-quality service across the entire sanitation chain, CBS becomes an effective sanitation system. In a study by [45], BoP households using CBS almost totally ceased open defecation, although some use of pit-latrines and public toilets remained.

2.2.2. CBS Services as an Enabler for Circular Economy

The activities in the sanitation chain resonate with the principles of the circular economy. Since the *user interface* of CBS systems are waterless, they are more adaptable to contexts with water scarcity. Depending on the desired utilization of these resources, collecting residuals in the purest possible

form, i.e., undiluted by flushing water, reduces the effort and additional inputs needed to process them later. This is extended further when source separation methods such as UDDTs use, allowing for the *containment*, and later conveyance and treatment, of urine separately from fecal matter. This has the added benefit for the user of reducing odor in the toilet [46].

In order for the effort put into extracting energy and materials from the products collected through CBS services to be attractive, products need to be collected swiftly and in sufficient volume. Here, more affordable and efficient *conveyance* technologies are needed to support the decentralized transportation of excreta and urine between households and treatment sites [47].

Finally, the different *treatment* options taken by CBS organizations are linked to their *reuse or disposal* choices (see Table 2). This reduces the amount of excreta that is dumped into water-bodies or applied to land untreated, which poses health and environmental hazards [48]. CBS organizations rely on robust and safe treatment options, many of which convert excreta into marketable end-products. For example, if the excreta is properly composted it forms a nutrient- and carbon-rich soil amendment [49].

Some CBS organizations regard the excrement as an energy carrier and harness this energy. This can be done via anaerobic digestion, a process by which organic matter is broken down in the absence of oxygen, resulting in a gas that is predominately a mixture of methane and carbon dioxide. This gas can be combusted and used in generators or in special cooking stoves. Collected organic matter can also be used as a component in solid fuels, like briquettes that are combusted for industrial, agricultural, or cooking purposes [50,51]. Alternatively, excreta can also be fed to Black Soldier Fly larvae [52], which are rich in both fat and protein. These larvae can be reared and harvested for use as an animal feed directly or as an input for industrial feed [53]. The lipids contained in them can be extracted for conversion into fuels [54].

3. Research Methodology

3.1. Data Sampling

We used a purposeful sampling process [55]. Over the course of several years, the research team has been engaged in projects with five CBS organizations, each serving between 100 and 1500 households. All five CBS organizations agreed to participate in the study. Three of them (Cases A, B, and C) agreed to participate in our main digitalization study. In this main study, we conducted a series of interviews about the digital transformation. Two of them (Cases D and E) agreed to share information about their current status of the digital transformation. We used a "replication", rather than "statistical" logic. The main cases provide CBS services in Madagascar, Kenya, and Peru, the later two in Haiti and Kenya. For theses two additional CBS organizations, we collected the necessary information on the current status of the digital transformation through secondary data.

3.2. Data Collection

For the series of interviews, we gathered data through in-depth interviews with key decision makers who played a vital role in the process of introducing digital technologies into the CBS services. For each of the three case studies, we conducted three to five interviews, resulting in a total of 12 interviews. The interviews lasted about an hour each. We phrased questions in an unobtrusive and non-directive manner, so as to avoid the pitfalls of excessive active listening [56]. We facilitated the emergence of the insights into the digital transformation as an enabler for advanced sanitation services, grounded in the interviewee's own language, rather than using pre-defined constructs.

The interviews were semi-structured. Our interview guidelines included questions requesting clarification, examples, and more details on potentially useful digital technologies for CBS organizations. In the first part of the interview, we asked for details on the current challenges for providing CBS services in the BoP market. Thus, we gained an understanding of each organization and its efforts to operate and grow CBS services. In the second part, respondents indicated how

digital technologies can help them to cope with these challenges. To facilitate the process, we asked participants to provide examples of specific successes in their digital transformation. We attempted to understand how certain activities in the digital technologies contribute to operation and growth of CBS services and how the lack of digitization led to failures. In the third part, we asked interviewees about their general approach in the digital transformation. The interviews concluded with respondents describing themselves and their personal background.

The interviews were supplemented with other types of primary data including workshops and site visits and secondary data including publications for triangulation purposes. Altogether, these data were compiled as longitudinal case studies describing the role of digital technology in the development and growth of these organizations over the course of three to five years.

3.3. Data Analysis

These case studies were systematically and iteratively analyzed through within and cross-case analysis. The within-case analysis of the digital transformation formed the starting point of the data analysis. This procedure enabled the research team to become familiar with each case, which accelerated the cross-case comparison. A generic technology stack framework assisted us in the within and cross-case analysis. This framework depicts the description of activities for the digital transformation and links this description to the relevant hardware and software devices, communication gateways, platform approaches, and technology applications.

To identify how digital transformation affects CBS services, researchers began by independently identifying the critical digital technologies mentioned in the case descriptions and interview transcripts. Any digital technology that emerged during the analysis were described in the margins and then labeled with descriptive codes [57]. Instances of digitalization exhibited by each organization were visualized using the technology stack framework and the influence of each of these applications of digitalization on the provision and growth of CBS services in each organization has been considered. For the purposes of this analysis, digitalization includes a wide variety of activities, ranging from transitioning paper-based records to a computer database to incorporating the Internet of Things (IoT) into their service delivery model.

The within-case study analysis allowed the challenges, digital technologies for coping with these challenges, and the general approach in the digital transformation, in each case to emerge before the research team proceeded to transfer the findings during the cross-case analysis [58]. The cross-case analysis is closely coupled with the within-case analysis. By doing a cross-case search, the research team used the elements that had been described either in the theoretical background or which emerged in the case analysis. During the cross-case analysis, the team looked for similarities and differences in the digital transformation across all case studies. This tactic forced the research team to look for subtle patterns in the digital transformation emerging from the case studies.

The within and cross-case analysis of the three cases was considered the point where theoretical saturation was reached. Of course, it is not enough simply to state that data collection and analysis are concluded once saturation is reached. Therefore, the following guideline was employed: the emerging challenges, digital technologies for coping with these challenges, and the general approach in the digital transformation were considered saturated if they were reflected in all case studies, confirmed by interviewee feedback, were consistent with the findings from the other two additional cases and if they made sense in terms of prior research [59].

4. Findings

Our findings are structured according to our research questions and data analysis into three sections. First, we highlight the challenges in providing CBS services. Second, we describe how our three cases invest into digital transformations to make CBS a successful advanced service. Third, we explore a framework to assist other organizations in BoP markets understand digital

transformations. The first two sections present the description of the findings, whereas the third section starts to interpret the findings.

4.1. Challenges in Providing CBS Services

Our case analysis suggests that all cases included in this study are currently investing into a digital transformation of their CBS services. This digital transformation is expected to solve some of the challenges of providing reliable CBS services. These challenges can be structured according to the activities in the sanitation value chain. According to the *user interface*, challenges arise in the advertisement and promotion of CBS services. Our organizations report high costs for creating awareness among households that CBS services would considerably improve their sanitation situation. Even if our organizations raise awareness of the benefits of CBS, it is difficult to convert interested BoP households into customers. These difficulties refer to identifying the responsible household member and arranging follow-up meetings and discussions with them. Our organizations often lacked the necessary customer insight to understand which customer characteristics trigger households to become customers. In addition, our case organizations report challenges in their sanitation marketing activities. Organizations invest significantly in such marketing activities, but have only a modest understanding of the efficiency and effectiveness these activities.

Once BoP families have become customers, our organizations report challenges in managing the customer relationships. These challenges refer to establishing a cost-effective payment collection. Many CBS organizations have struggled to efficiently collect subscription fees from their customers. When the majority of customers are un-banked, collecting payment can be time and labor intensive. Additionally, money collectors can be evaded by customers, who might not pay in full when found. Thus, they need to visit households multiple times and manage debts. Manual money collectors also pose a two-sided security risk: they could have money stolen from them or keep some of the collected money for themselves.

Furthermore, our cases reported challenges in retaining the customers. Since customers must regularly pay for CBS services, only highly satisfied customers continue to pay for the services. Some organizations report that they lack the information about the customer satisfaction and cannot quickly counteract drops in customer satisfaction and loyalty.

Considering *containment* and *conveyance*, an important trigger for achieving customer satisfaction is the regular and timely collection of the containers. Customers expect that the container collection follows a timely predefined schedule. Costs are relatively high due to the complexity of collection in densely populated urban areas with unreliable infrastructure (e.g., unpaved, bumpy, washed-out, and narrow roads). The organizations report challenges in monitoring the conveyance in terms of tracking and monitoring the different means of transportations and the containment options (barrels, bags etc.) in terms of excreta amounts. Our organizations find it difficult to guarantee collection schedules and to improve collection costs. Additionally, the dynamic adaptation of the collection schemes to the steadily increasing number of BoP customers increases the complexity even further. Organizations do not have sufficient information to plan, schedule, optimize, and/or simulate collection routes. Typical adaptations are the introduction of intermediate storage station for the containers and modifications in the collection routes.

According to the *treatment*, our case organizations report being challenged in monitoring the treatment processes. Monitoring includes tracking excreta amounts and guaranteeing that the treatment processes are safe and conform with the regulations. For example, when composting human excreta, the temperature of the compost must be monitored to make sure that it is hot enough for long enough so pathogens are killed, the duration of each batch must be logged, and it must be tested for remaining pathogens.

Finally, for *reuse and disposal*, organizations lack professional customer relationship management (CRM) tools to support the recruitment and management of customers for end-products and

sophisticated production systems allowing organizations to manage end-product volumes and deliveries accurately.

Across these sanitation value chain activities, our organizations report an additional layer of data management processes. In this layer, our organizations managed the various tasks with multiple computer spreadsheets and complicated paper records, in which data can be inaccurately collected and manipulated. Without the ability to monitor these activities and tasks, our organizations faced challenges organizing and sharing accurate information about their performance with investors, management teams, employees and customers.

4.2. Digital Transformations for Advanced CBS Services

Overall, these challenges restrict the operation and growth of CBS services. To better cope with these challenges, our case organizations have invested in digital transformations. Even if each of our case organizations focuses their digital transformation on certain elements of the CBS services such as marketing or collection, their digital transformations influence the entirety of their CBS service operations.

Digitization activities range from basic, such as keying handwritten collection records into a database, using accounting software, to bringing IoT to sanitation by adding QR-codes and NFC tags to containers. The organizations use a mixture of off the shelf and bespoke digital tools.

CRM platforms have been reported to be the keystones of each of the organizations' digital architectures, but the way data enter these platforms varies from organization to organization, as seen in Table 3. Some data flow automatically from where they are generated into these platforms, but others must be manually transfered between organizational units. The digital transformations of each case is described in the following sub-sections.

4.2.1. Case A

Case A invested in their digital transformation the promotion of CBS services through the introduction of Salesforce, a CRM software. Case A's sales agents are equipped with smartphones and an application called Formyoula, which is used to collect data from potential and existing customers. This application needs to work off-line, so the information can be collected when the employees are in neighborhoods that have unreliable mobile signals. Once the application is synced with Salesforce, a customer profile is created. Case A is now able to automatize sales lead generation for new customers and to obtain customer data. Through these customer data, Case A is able to make better decisions about their marketing approach. Once a potential customer becomes an actual customer, their service history and other behavioral data are stored in this customer profile.

Similarly, Case A invested in the digital transformation of container logistics, by placing NFC tags on most of their barrels. Smartphones and an application built with Open Data Kit (ODK) introduced to register the pick-up time and condition of the containers. Through this automatized information gathering on pick-up times, Case A could visualize the service quality making it easier to respond to any deficits in punctuality of the collection teams.

Scanning the NFC tag also notifies the collector that a customer has not paid and gives the collector the opportunity to make notes about the condition of the container, in case the user needs to be reminded of correct usage practices. Case A finds it is now easier to maintain customer satisfaction and loyalty. Automatized information about collection informs decision-making about collection frequency in terms of switching from a weekly to a biweekly collection and vice versa.

Interestingly, the introduction of mobile payments plays a vital role for the digital transformations of Cases B and C, Case A's customers pay at kiosks in selected stores and pharmacies through a service from a national bank. A store clerk inputs the bill payment into a computer and the money is then transfered to Case A's bank account. By uploading these payment data to the customer profiles in Salesforce, case A can monitor whenever payments are not on-time and/or fail.

Table 3. This table shows the digital technological stacks of each of the organizations at the time of case study construction, according to the interviews and publications.

Case	Description	Device hardware	Device Software	Communication Gateway	Platform/Backend Systems	Application of Technology
A	Introduction of CRM software (before a mixture of spreadsheets and paper)	Computer	Salesforce	Internet/cloud	Salesforce	Tangible information for creating strategy (data-based decisions)
	App to collect data on existing and potential customers while in the field	Smartphone	App (Formyla)	Internet/cloud		Lead generation, accounting
	Each pick-up is registered & condition of bucket	Smartphone	ODK-based App	Internet/cloud		Usage/Behavioral corrections
	NFC tags placed on lids of some containers (pilot)	Container with NFC tag, Smartphone		Local storage -› Internet/cloud	Excel	Waste collection check
	Payment collection via local stores/pharmacies	Computer	Shop employee keys in payment to Bank's software	Internet/cloud	Proprietary Bank download/uploaded to Salesforce	Dashboards, Reports, and Graphs
	Team Communication	Computer/tablet	Evernote	Internet/cloud	Evernote	Weekly briefing
		Smartphone	Slack App	GSM, Internet	Slack	Specific chat groups, sharing files
B	Development of CRM software	Computer		Internet/cloud	In-house CRM Platform	Dashboards
	Payment collection reminder/bill via SMS (SMS sent form CRM to customer)	Computer, mobile phone	Proprietary from phone company	Internet -› GSM		Reports and graphs
	Mobile Payments	Mobile phone	SMS sent form CRM to customer	GSM -› Internet/cloud		In person visits for service, usage trainings and payment collection
	Digitization of paper records of condition of the toilets at collection	Computer	Excel/GoogleSheets	Internet/cloud		Data are accessible
	Route check after collection (route overlaid with customer locations)	GPS tracker	myMaps	GPS, Internet/cloud	Google Maps	Payment collection, accounting
	Accounting software	Computer	QuickBooks	Internet/cloud	QuickBooks	Customer retention, heightened service level
C	Development of App and Web-platform for CRM	Computer, tablet	App, Web-platform	Internet/cloud	In-house CRM Platform	Data management
	Greenline—Customer service request via texting codes	Mobile phone	Proprietary from phone company	GSM -› Internet/cloud		Dispatch of person to attend to issue, on demand collection
	Mobile Money payments (40%)	Mobile phone				Payment check
	System tracking via QR codes	QR codes—toilet, smartphone	Smartphone app scans QR code	Internet/cloud		Collection check
		QR codes—collectors, smartphones				Reporting KPIs
		QR codes—customer, smartphone				M&E
		QR codes—refills, smartphone				Accounting
	3-D printing of spare parts	3-D printer	AutoDesk	Internet/cloud	AutoDesk	Generation of precision spare parts

4.2.2. Case B

Case B is undergoing a similar digital transformation, but less emphasis is placed on promoting of CBS services through digital technologies. Case B has just gone beyond the pilot phase and has not yet promoted CBS services on a larger scale. Thus, Case B focuses on digitalizing the payment schemes for the existing customers. Payment reminders and promotions are sent via SMS from their custom built CRM system. They encourage payments to be made with mobile money, based on standardized money transfer and communication services offered by the local telecommunication provider.

Case B's collectors make a note of the condition of each bucket using pen and paper and this information is typed into a database afterwards. They have implemented other technologies for digitalizing the collection procedures. During the collection of the excreta, collectors carry a GPS-tracker. After each collection, the GPS information is visualized in myMaps making it possible to compare collection routes with the actual customer locations. Case B can now easily check whether all customers have been served and whether collection was timely.

4.2.3. Case C

Case C introduced a supply chain tracking system. Case C attaches QR-codes to toilets, containers, and refills. Employees use smartphones to scan these codes automatizing part of the information gathering process. During the collection, QR codes of the containers are scanned and weighed and the collector types the weight into the application. This process is repeated when they arrive at the treatment site. Thus, Case C can verify that all of the excreta that has been collected arrives at the treatment site. To make their supply chain more robust, Case C has engaged 3-D printing technologies. To avoid long shipping times and irregular customs duties, Case C uses a 3-D printer to manufacture select replacement parts with precision that exceeds the quality available locally.

Like Case B, Case C encourages payment via mobile money and about 40 percent of their customers use this option. They use another mobile technology to enhance the level of service they can provide their customer, a "greenline". The greenline allows their customers to send them free SMS messages to request services such as repairs or a special collection. These requests are automatically sent to their web-based CRM platform, allowing them to easily dispatch technicians and track trends.

Overall, Cases A, B, and C reveal detailed evidence on the digital transformation of advanced CBS services, with digitization being seen in the logistics, information management, and payment collection aspects of their operations, as summarized in Table 4. These case descriptions are consistent with the experience of cases D and E. Case D leveraged its digital experience with the introduction of Salesforce to its donor program. Here, Case D used the Salesforce functionalities to manage the relationship with donors and reoccurring contributions. They are considering leveraging this experience to also equip its sales agents with Salesforce and are thinking about the introduction of mobile payment systems. Case E has fully implemented mobile payment schemes and has digitalized its operational processes for manufacturing toilets, for collecting and processing waste, as well as for selling end-products.

Table 4. Digitalization can be seen in three areas of operations of the organizations: Logistics, Information Management and Payments.

	Logistics	**Information Management**	**Payments**
Case A	NFC Tags + ODK App	Salesforce + Formyoula App	In-shop bank payments
Case B	GPS route recorder	Own database + SMS	Mobile Money + QuickBooks
Case C	QR-codes + 3D printer	Web Platform + Greenline	Mobile Money

4.3. A Framework for the Digital Transformation of Services in BoP Markets

Comparing and aggregating the data from the case studies leads to a more general framework for the digital transformation in BoP markets. This framework contains three elements: (i) digital reality, (ii) digital ambition, and (iii) digital implementation. These elements can be considered iteratively,

i.e., lessons learned during implementation better inform an organizations understanding of the digital realities of their context and what ambitions are relevant and realistically achievable.

4.3.1. Digital Realities

Organizations should start the digital transformation by recognizing the digital reality in BoP markets. On the one hand, BoP markets have various disadvantages for the digital transformation. For example, the collection applications needed to be designed for use by people with limited literacy. They needed to be "light" (i.e., not requiring too much memory as the smartphones that the organizations have access to are somewhat dated) and yet function off-line, since mobile signals can be weak, unreliable, and non-existent in areas where these organizations operate. On the other hand, because of the social motivation for serving the BoP population, socially oriented organizations can access critical resources, e.g., paying reduced software license fees (or receiving them for free) and accessing grants for developing and implementing digital innovations.

4.3.2. Digital Ambition

In this phase, digital ambitions are developed. Goals for digital transformations should be set and relevant activities should be prioritized. Goals can relate to time, costs, and quality. To prioritize relevant activities, our cases try to identify best practices of the digital transformation in other BoP markets. Organizations need to look for the actual enablers for the digital transformation. These enablers include:

Digital data: The acquisition, processing and evaluation of digitized data make it possible to make better predictions and decisions. Such predictions and decisions are, for example, important for improving sanitation marketing activities and for reducing collection costs.

Automatization: The combination of classical technologies with artificial intelligence enables the creation of autonomous, independent, self-organizing and working systems. This makes it possible to reduce costs and lower error rates in the collection processes, for example.

Digital customer access: The mobile internet provides direct access to the customer, thereby providing high transparency and new services. Such access via mobile phone and payment schemes entails a high transparency and deep insights into the customer behavior. Once such access is established, additional services (e.g., hygiene products) can be marketed to the customers through these channels.

Networking: The mobile networking of the entire value chain via telecommunications enables the synchronization of supply chains, which leads to a reduction of production times and innovation cycles. For example, such innovation cycles were evident as developers learned how to adapt their offerings to the contexts of different BoP markets.

These enablers lead to a variety of options for digitalization. Therefore, this phase also includes achieving an actual fit and coherence among these options. The coherence and fit observed in our cases was based on prioritizing the digital transformation for the user interface and conveyance. Case A created coherence among options on using Salesforce, Formyoula application, and in-shop bank payments for improving user interface and on using NFC tags and ODK application for optimizing the collection logistics. Case B achieved coherence on developing its own customer database, SMS alerts, mobile money application and QuickBooks accounting software program for improving the customer relationship and GPS route recorders for improving collection logistics. Case C's coherence relies on their web-platform that uses data from their greenline, QR-codes, and mobile payment system and 3-D printers for improving toilet manufacturing and collection costs.

Digital ambition needs to be managed in a way that unifies short term impact with long-term vision. The idea is that the data collected now, will be useful in developing future strategies; therefore, the digital ambition should look beyond the existing scale. Smartphone applications and use of IoT may not really be necessary for the day-to-day operations when the organization has a few hundred toilets, but in order to grow, they need to understand their customers' usage patterns and other

behaviors and their digitalization initiatives will allow them to collect and understand the necessary data. Our cases view their investments into digital transformations as assets that can be used for future replication or franchising opportunities.

As illustrated in Table 5, digitalization initiatives were targeted either at the user interface and conveyance aspects of the sanitation systems or served back-end administrative functions, which supports the coherence of digitization options for cases A, B, and C. The introduction of digital tools to the customer-facing sections in the sanitation chain, indicates that the organizations are targeting the aspects of their service that help them gain and retain customers. They have enhanced their value proposition by introducing new lines of communication, service quality assurance practices, and seamless billing and payment processes. Internally, they have built a single place for all of their data to be stored, making it simpler to generate reports.

Table 5. CBS providers have introduced digital technologies on the front-end of the sanitation chain.

	User Interface	Containment	Conveyance	Treatment	Reuse or Disposal
Case A	• NFC Tags • Bank Payments		• NFC Tags		
Case B	• Mobile Money		• GPS		
Case C	• 3-D Printed Parts • Greenline • QR-Codes • Mobile Money	• QR-codes	• QR-codes	• QR-codes	

The cases expressed future ambitions for integrating digital components into their treatment processes and recognized the need to manage inventory information and records about the condition of toilets digitally. Toilet condition is important, since the calculation of costs for the CBS services is based on an estimation of the toilet life-cycle costs (e.g., toilet lifetime and maintenance costs).

To make the entire digital ambition realistic and easily to implement in the future, CBS organizations are exchanging experiences with each other to strengthen their systems and may collaborate more formally in the future.

4.3.3. Digital Implementation

Digital implementation is about circumventing the various obstacles in the BoP markets. Our cases either used internal funds to pay a local developer to facilitate the digital transformation or received individual external grants to build out their technological stacks by working with international software developers. Developers made site visits and taught employees to use the systems. High-level staff needed to divert time away from daily operations to help developers understand the harsh conditions in which the systems would need to function and the reality of their operations. The organizations had to reach an understanding of what was technically feasible and the developers needed to better understand the context. The mobile applications had to be designed to accommodate the collectors who wear gloves and other personal protection equipment on the job.

Another obstacle with implementation concerns promoting customer acceptance of the use of digital tools. Sanitation is particularly private and personal and customers can feel uncomfortable with their excreta being logged in a computer. Similarly, even if customers accept certain digital solutions, it is questionable whether all customers will do so. When introducing mobile money payments, where customers pay using credit that has been loaded onto their mobile phone, the question is whether this should be mandatory or not—it would be much easier for the CBS organizations if it were, but not all of their customers have access to these platforms. Paying with mobile money is not yet mandatory, but the cases encourage it by limiting the ways they accept cash. Our organizations have

had to work directly with individual customers to make them feel comfortable using these platforms, e.g., by teaching them individually how to purchase credit and execute payments.

5. Conclusions

The starting point of our study was that CBS services represent advanced services, which can play a vital role for improving the sanitation conditions in the BoP markets. It was shown that (1) CBS services face many challenges, (2) organizations tackle these challenges through a digital transformation of the CBS services, and (3) organizations progress through digital transformations by understanding the digital realities in BoP markets, formulating a digital ambition, and implementing this digital ambition.

5.1. Theoretical Implications

The conceptual framework developed and justified empirically in this paper contributes to a better understanding of digital transformations in BoP markets. The core argument is that organizations need to develop their ability to formulate and implement the most appropriate digital transformation pathways, in order to enhance the provision of advanced services in BoP markets.

Our findings substantiate previous contributions on digitization. They conform with the general idea of digital opportunities in BoP markets [27]. The coherent options in the digital ambition are in line with the importance of digital technology platforms. The various digital initiatives were observed to be distributed in different sanitation activities and the overall digital transformation result from combinatorial innovations [18]. Digital transformation of CBS services highlights the importance of the user experience, digital evolution scanning, and improvisation [13]. Improvisation was observed in digital implementation, where user interface was a major objective for the digitization, and organizations in the BoP markets continuously scan for digital opportunities. Digital transformation strategies in BoP markets also span across corporate, operational, and functional strategies [16]. Compared to previous contributions focusing on single digital technologies (e.g., mobile payment technologies and remote monitoring) [25,26], our findings provide a comprehensive perspective on multiple digital technologies.

Finally, our findings substantiate previous descriptions of digitization capabilities for advanced services. Organization in BoP markets require digitization capabilities for identifying sanitation users and products, intelligence, connect, and analytical capabilities for optimizing sanitation marketing activities, reducing collection costs, and improving treatment processes, and orchestrating the role of back-end and front-end units [19–22].

5.2. Managerial Implications

Our results have implications for managers. Managers should vigorously pursue digital transformation in order to cope with the challenges of providing services in BoP markets. Tables 3 and 4 show example of how organizations utilize digital technologies. Managers can compare the described courses of action with their own approaches toward digitization. In addition, our descriptions of obstacles for the digital realities, digital ambition, and digital implementation offers a practical guideline to avoid pitfalls. Practitioners must, however, ensure that they are not fully absorbed by a single digital technology option. They should recognize the importance of pursing multiple coherent digital options, specifically, in marketing, payment and logistical activities. Managers should develop these digital initiatives strategically, but at the same time should be aware of the need for digital improvisation.

5.3. Limitations and Future Research Opportunities

This paper explores digital transformation as an enabler for advanced sanitation services, rather than testing certain hypotheses on the benefits of digitization for the sanitation sector. As with all qualitative research, the transferability of the findings is limited. We tried to improve the potential

for transferability through a rich description of the key elements in the framework on digitization and sanitation, from which other researchers can evaluate the transferability to other services in BoP markets. We also included multiple countries. Nevertheless, the extent to which the results are transferable remains open.

Since digital transformation in BoP markets is still an emerging research domain, our findings are not meant to be exhaustive. A natural progression would be to transfer our insights into the digital transformation to other services offered in BoP markets. These services might show different patterns. For example, researchers can apply our findings to solar home systems, water treatment equipment, and cooking stoves in BoP markets. Such a transfer would provide a noteworthy contrast, revealing new insights into digital transformations in low-income markets. Although these limitations must be kept in mind, we are confident that our findings provide new insights for academics and practitioners alike.

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Abbreviations

The following abbreviations are used in this manuscript:

BoP	Base of the Pyramid
CBS	Container Based Sanitation
CHP	Combined Heat and Power
CRM	Customer Relationship Management
GPS	Global Positioning System
IoT	Internet of Things
ODK	Open Data Kit
QR-Code	Quick Response
RFID	Radio-frequency identification
SDC	Swiss Agency for Development and Cooperation
UDDT	Urine Diverting Dry Toilet
WASH	Water, sanitation and Hygiene

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