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Innovation process and uncertainties in resource-constrained environments: A case from the water service sector in East Africa

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ABSTRACT

Innovation processes face significant and not well-understood uncertainties in resource-constrained environments in developing countries. Through a case study of a water innovation process focused on Kenya, this article studies the prevailing uncertainties and management principles. With the help of a framework that combines information on technological, organizational, commercial and social aspects, our study identifies uncertainties in four distinctive stages of resource-constrained innovation: (1) Ideation and conceptualization, (2) Learning-based product and business development, (3) Scrutinized product and business development and (4) Commercialization. We recognize three principles required to manage uncertainties and develop successful resource-constrained innovations: (1) the utilization of versatile research and development approaches, (2) building internal acceptability, trust and legitimacy and (3) leveraging range of partnerships and networks to access complementary resources and capabilities in different process stages. Our findings suggest that management of uncertainties requires proactive utilization of partner networks and context-specific strategies in different stages. With this research, we contribute to the understanding of innovation processes by advancing process-based knowledge of water innovation, uncertainties and related management strategies in resource-constrained environments.

1. Introduction

The world's largest socio-economic group, conceptualized as the Base-of-the-Pyramid (BOP), consists of about four billion people living close to the poverty line in developing areas (Prahalad, 2012, 2004). These people are often faced with various additional constraints—such as limited access to water—to which market-based approaches and innovation are proposed as a medium. Even though the discourse linking poverty alleviation, innovations and business activities emerged over a decade ago (Hart and Christensen, 2002; Prahalad, 2004; Prahalad and Hammond, 2002; Prahalad and Hart, 2002), (Hart and Christensen, 2002; Prahalad, 2004; Prahalad and Hammond, 2002; Prahalad and Hart, 2002), various aspects related to such linkages are not thoroughly understood and/or remain contested (Pansera, 2018; Smith et al., 2014).

The existing innovation literature has focused mainly on the qualities and types of products, services and business models, as well as on technological features and organizational practices (Gebauer et al., 2017; Gebauer and Saul, 2014; Rao, 2013; Ray and Ray, 2011; Rosca et al., 2017; Seelos and Mair, 2007; Winterhalter et al., 2017, 2015). Resource-constrained innovations' implications and linkages to sustainable development have also raised interest (Hyvärinen et al., 2016; Levänen et al., 2015). Less attention has been paid to the complexity, cost and time-consuming nature of resource-constrained innovation processes, sectoral peculiarities and the different roles partners have in different phases of the innovation process. Furthermore, the great number of diverse uncertainties prevalent along the innovation process—and their management strategies—remain understudied (Böhle, 2011; Hall et al., 2014b, 2011; Melander and Tell, 2014) although overcoming them is a precondition for successful innovation.

The United Nations' Sustainable Development Goals (SDGs) (United Nations General Assembly, 2015) emphasise the role of the private sector and partnerships in solving global development challenges. The SDGs address several water-related challenges such as the provision of

Abbreviations: ATM / water ATM, Automated teller machine: Automatic water dispensing machine with an integrated mobile prepayment and real-time monitoring system; BOP, Base-of-the-Pyramid; NGO, Non-governmental organization; O&M, Operation and Maintenance; R&D, Research and Development; SDG, Sustainable Development Goal; TCOS, Technological, Commercial, Organizational and Social; WASH, Water, Sanitation and Hygiene

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water supply, sanitation and hygiene (WASH), which is generally seen as the responsibility of the public sector—namely the central and local governments. While the SDGs set ambitious targets for WASH, several areas remain underserved and in need of novel solutions. For example, in Sub-Saharan Africa 39 % of the population lacks access to basic drinking water services, 69 % to basic sanitation services (UNICEF and WHO, 2019), and implementation and governance challenges are common (Yinusa and Wehn, 2016). The water services sector provides therefore a good example of an operational environment that can create new opportunities for private sector engagement and innovation, but also generates diverse uncertainties for companies' innovation processes (Annala et al., 2018; Gebauer and Saul, 2014; Karnani, 2007; Sousa-Zomer and Cauchick Miguel, 2018) and call for new policies (Leach et al., 2010).

In this article, we study the uncertainties that shape the resource-constrained innovation process in the water services sector in Kenya. While water is physically scarce in certain regions of Kenya, it is also common that the lack of sustainable water services stems from institutional and operational challenges (Foster and Hope, 2017; Whaley and Cleaver, 2017; Yinusa and Wehn, 2016). Many water points and even utilities lack optimal revenue collection approach, operation and maintenance schemes as well as funding. Unsuitable technologies and inadequate skills and capabilities further impede service sustainability. Poverty hampers access to all kinds of services, including water and sanitation, with low-income people often in the most vulnerable positions, spending more time and money to access water. These aspects underline the need for new solutions and ways of working in the water sector—including private sector engagement and innovations beyond technological solutions. Our study focuses on the entire innovation process of Grundfos Lifelink, which aims to meet the sustainability challenges in the water sector in resource-constrained environments such as Kenya. We analyse the diversity of uncertainties faced during Lifelink's ten-year development process, and identify principles for strategies utilized in managing the uncertainties. Our hypothesis is that an agile variety of approaches and a range of partners are required for resource-constrained water innovation.

Frameworks for evaluating innovations and the embedded uncertainties traditionally focus on technological and commercial viability as well as on companies' capability to generate return on the investment (Hall and Martin, 2005; Jalonen, 2011; Matos and Hall, 2007). Social uncertainties, which are often external to the individual company, have attracted less interest (Hall and Martin, 2005). Yet, we argue that managing social uncertainties with appropriate strategies is particularly important in resource-constrained environments. To understand the diversity and evolution of uncertainties, we utilize in this article the TCOS framework, which distinguishes Technological, Commercial, Organizational and Social forms of uncertainty (Hall et al., 2014b, 2011; Hall and Martin, 2005)..

To our knowledge, this article presents the first chronological, process-based study that looks systematically at the management of uncertainties throughout the entire resource-constrained innovation process. Theoretically, we provide a novel way to apply the TCOS framework to understand the innovation process and uncertainties in different stages. Our practical aim is to use the gained understanding to recognize the key principles for the successful management of such uncertainties. This article is guided by the following research question: What are the key uncertainties throughout a water innovation process in a resource-constrained environment, and how to manage such uncertainties? Through such a question, we also depict the stages of the resource-constrained water innovation process.

The article is structured as follows. The general context for our research is presented in this section, followed by a short section that sets the scene for innovations in resource-constrained environments such as Kenya. The third section describes the research methodology, data sources and analysis, as well as the case. The fourth section presents the analysis and key findings from our case, synthesising first the four distinctive stages of the innovation process and then describing the key uncertainties across the innovation process. Following that, we discuss the three principles we recognise for the strategies to manage such uncertainties. Finally, we discuss the key implications of our study, followed by brief conclusions.

2. Innovation in resource-constrained environments

Innovations usually build on the affluence of resources (Prahalad and Mashelkar, 2010). Yet in developing countries, innovations largely stem from the scarcity of material resources, limited affluence of customers, lack of time, and environmental and institutional constraints (Cunha et al., 2014; de Georgio Ferrari Trecate et al., 2020; Duker et al., 2020; Pansera and Owen, 2015; Ramani et al., 2012). New narratives, models, and conceptualizations of resource-constrained innovation are emerging (Foster and Heeks, 2013; Hossain, 2020; Mulgan et al., 2007; Mvulirwenande and Wehn, 2019; Radjou and Prabhu, 2014; Sarkar and Pansera, 2017; Smith et al., 2014; Williamson, 2010; Zeschky et al., 2014), all characterized by an aim to respond to the needs and desires of the people in resource-constrained environments by combining a market-based approach with social and/or environmental values (Cunha et al., 2014; Pansera and Owen, 2015; Zeschky et al., 2014).

The process of developing resource-constrained innovation is described as continuous learning and refinement (Prahalad, 2012). Traditional models for managing and conducting innovation suggest that the process consists of a rather linear and sequential set of activities, with screenings for continuation in between idea generation, idea selection, development and launch/commercialization (Cooper, 2008, 1990; Cooper and Sommer, 2016; Rothwell, 1994; Utterback, 1971; Wheelwright and Clark, 1992). At the same time, various uncertainties, institutional voids and complexities prevalent in resource-constrained environments shape the innovation processes and their outcomes (Karnani, 2007; Khanna and Palepu, 2010; Mair et al., 2012; Olsen and Boxenbaum, 2009; Sinkovics et al., 2014). As a result, a more iterative approach is advocated, together with a collaborative partnership and the frugal use of technology and resources (Ray and Ray, 2011). While traditional innovation process models remain influential, they may not fit well in such environments—this is often the case with new markets and/or technological breakthroughs (Salerno et al., 2015). Besides processes and outcomes, understanding and addressing innovation-related uncertainties is also a focal point for the development of adequate and effective innovation management strategies.

To innovate in resource-constrained environments, organizations need to tap into new types of knowledge, resources and capabilities and develop differing strategies, organizational structures, practices, business models and R&D processes (Gebauer and Saul, 2014; Hart et al., 2016; Hart and Christensen, 2002; London and Hart, 2004; Wehn and Montalvo, 2018a; Winterhalter et al., 2015; Zeschky et al., 2011). Collaboration and partnerships, especially with local organizations, are typically important and leveraged in resource-constrained innovation. Partners, such as non-governmental organizations (NGOs), international organizations, local entrepreneurs, government agencies, universities and even the BOP, can hold a diversity of roles (Hietapuro and Halme, 2015; Hyvärinen et al., 2016; Kolk et al., 2014; Ramani and Mukherjee, 2014; Rivera-Santos et al., 2012a; Webb et al., 2010). Partnerships enable exchange of complementary resources and co-creation of solutions (Mvulirwenande and Wehn, 2019; Wehn and Montalvo, 2018a) and better innovation diffusion (Ramani and Mukherjee, 2014). In addition, local organisations have been shown to diminish the social and institutional distance that multinational enterprises often face in developing markets (London and Hart, 2004; Rivera-Santos et al., 2012b; Webb et al., 2010).

Finally, it is important to note that innovation in resource-constrained environments is a multi-dimensional, often politically sensitive, and sometimes disputed idea (Arora and Romijn, 2012; Karnani, 2007). Concerns have been raised about the recipients of benefits:

whether it is only the companies developing solutions or the users as well (Pansera and Owen, 2018). Similar concerns have been raised on the sustainability of the users' participation in the innovation process (Sandman et al., 2018; Steen, 2011). It has also been argued that innovations may end up maintaining or even strengthening unequal power structures and environmentally harmful market models (Pansera, 2018). These critical perspectives on innovation management are especially relevant in developing countries, where people cannot necessarily afford new basic products and services, even though they may be innovative from the perspective of sustainability or societal development (Pansera and Owen, 2018).

3. Research methodology and data

3.1. Research methodology and analytical frameworks

We apply a case study as the key research methodology (Eisenhardt, 1989; Yin, 2014), and make use of a variety of methods to collect data on our case. The case study is complemented and compared with an extensive literature review focusing on innovation management in resource-constrained environments. Such a methodology enables us to profoundly explore the context and structure of the entire innovation process.

The studied case is the first commercially oriented resource-constrained innovation venture developed and implemented by Grundfos, a western multinational company. It is considered to be a representative case in providing a view to a water innovation process conducted in a resource-constrained environment due to the process and outcome characteristics, and the attention such innovations have received (Foster and Hope, 2017; Komakech and Kaemdin, 2019; Whaley and Cleaver, 2017).

Two frameworks are used for structuring our analysis. Firstly, we draw on chronological innovation stages (Rothwell, 1994; Salerno et al., 2015; Utterback, 1971; Wehn and Montalvo, 2018b) to describe the development of the studied innovation process over time. We utilize and move between innovation process literature and our data to define the key stages of the studied innovation process. Secondly, we use the TCOS framework (Hall et al., 2011; Hall and Martin, 2005) for identification and thematic categorization of uncertainties along the innovation process. TCOS framework's theoretical constituents are in innovative uncertainty, innovation value-added chain, and stakeholder analysis. The framework characterizes innovation uncertainties under four categories, which must be overcome before a solution qualifies as a successful innovation (Hall et al., 2014b, 2011; Hall and Martin, 2005):

- Technological uncertainty: Technological feasibility and functionality of the innovation
- Commercial uncertainty: Commercially viability and market/industrial success of the innovation
- Organizational uncertainty: Innovation's consistency with the company's overall strategy and capabilities, capability to appropriate the benefits of the technology, and organization and management of resources and capabilities to capture profit
- Social uncertainty: Societal acceptability of the innovation and stakeholder impact.

For this study, the strength of TCOS lies in its broad yet clearly structured scope: we utilize the four categories to structure our research and to recognize key uncertainties. The framework includes social uncertainties -typically a key concern in resource-constrained innovation- which can provide socio-political legitimacy for technologies and reduce future technological and commercial (Hall et al., 2011). Understanding them is of principal importance, especially for western companies who are used to operating in a different socio-economic and political environment (London and Hart, 2004). We use the two frameworks in two complementary ways to structure our analysis: first we apply both frameworks for the thematic uncertainty analysis at different innovation process stages (Table 2 and Supplementary Material), and then the TCOS framework as an auxiliary tool for recognizing principles for uncertainty management strategies along the process (Section 4).

As a single case study, the limitations of this study are related to the generalization of the results. The case study focuses on the development of a novel application to improve water service delivery, financial sustainability and operational transparency at communal water points in Kenya. Thus, the conclusions and implications presented might not be valid in other sectors and in different contexts. We seek to enhance the applicability of the results by reflecting our results against the literature and similar studies (Section 5).

3.2. Data sources, collection and analysis

An abductive approach is adopted to collect and analyse data for the selected case study, enabling continuous movement between empirical and theoretical worlds (Dubois and Gadde, 2002). The data collection is based on a variety of research methods across scales, including: (1) Five semi-structured key informant interviews with the executives of the case company in 2016 and 2017 (see Appendix A); (2) field observations, three interviews with the case company's local employees, and five user interviews in Kenya in 2016 and 2017 (see Appendix A); and (3) the gathering of relevant documentary material (secondary data) in the form of news, company reports and websites, videos, blogs, expert reports and academic publications (see Appendix A).

The main topics covered in the semi-structured interviews with key informants included (1) Innovation process and its stages, (2) Organizational aspects, (3) Uncertainties and their management along the innovation process (resources, capabilities, partners and collaboration in the value chain), and (4) Features and qualities of the innovation. Documentary material was utilized to construct the history of the case from 2007, and to complement and compare the results from the interviews and field observations. Of particular importance to understand the first years of Grundfos Lifelink was the conference publication by Andersen (2011).

The studied innovation process was first chronologically mapped to recognize key activities and stages of the process and to observe changes between product, business model, and market development activities as well as managerial aspects (Table 1). This was followed by an analysis of the data with the help of the TCOS framework. The data was coded respectively using ATLAS.ti software, and the uncertainties along the process stages were recognized (Table 2). The principles for uncertainty management strategies were identified with the help of coding, including codes for R&D approaches and metrics, external and internal resources and capabilities as well as internal acceptance and support. Lastly, another loop of data analysis was conducted to ensure the suitability of the selected TCOS framework and categories for management approaches. Further interpretation of data was utilized to identify and cross-check the means for managing uncertainties.

3.3. Case overview: Grundfos Lifelink

Grundfos is one of the leading pump manufacturers in the world. Besides traditional Grundfos products, a range of other solutions are developed in the more independent New Business unit (Grundfos, 2008). One of these is the Grundfos Lifelink organization, established in 2007 with the objective of developing and commercializing innovative water service solutions and business models for the developing markets, including BOP, where sustainability, equal access and maintenance of water services remain inadequate.

Lifelink is Grundfos' first commercially-oriented initiative for the BOP markets. Based on previous experiences and knowledge gained through corporate social responsibility activities and philanthropy, the Lifelink solutions were set to solve common water service challenges,

Table 1
The key water innovation process and solution qualities across four main stages of the Lifelink's innovation process.

Water innovation process in a resource-constrained environment	Ideation & conceptualization 2007–2008	Learning-based, product & business development 2009–2013	Scrutinized product & business development 2014–2015	Commercialization, multi-partnership model 2016
Approach including main product, business model, and market development activities	Iterative approach, rapid prototyping Evaluation of commercial potential and feasibility Small independent Lifelink team working freely Prototypes manufactured by a development partner Collaboration with local NGOs Local presence and knowledge gradually strengthened Mobile payment interface co-developed with Safaricom (local) and later Vodacom (global)	Iterative approach, testing prototypes, learning from the field Market experimentation and understanding application requirements, customers and willingness to pay – confirming value proposition Towards more structured way of working, KPIs: lessons per dollar Engagement of local NGOs, consultants, customer partners Active role in community management and capability building	Formal state-gate development process Verification of technological aspects and commercial viability Outsourced manufacturing brought in-house, price lowered 80 % Local role decreased Strategic partnerships developed for downstream activities, including global NGOs and local service providers Utilizing globally operating corporations as partners e.g. Ericsson mobile interconnect removed the need to negotiate with all operators	Lifelink product range development integrated to more traditional processes of Grundfos Grundfos-wide commercialization, scaling up Grundfos focuses on innovation, R&D, sales to traditional customers. Lifelink focuses on new markets More traditional KPIs: e.g. standard unit cost, warranty rates Strong partnerships for downstream activities, including sales and local community engagement
Solution qualities	1 st generation Lifelink water ATM - Mobile payments, water cards - Online water management system - Increased sustainability of water points - Water payments and community loans to cover investment - Complete water kiosks including, e.g., pumps, solar panels	2nd generation Lifelink water ATM - Multiple water outlets - Efficient revenue collection - Water credit transfers between users - New requirements: rigidity, low service needs, easy to use and maintain - Water payments to increase sustainability, not covering all costs	3rd generation Lifelink water ATM - Mobile payments with various operators supported - Programmable logic controllers replaced with embedded software, i.e., printed circuit boards - Size and weight of ATM reduced - Water ATM as a separate product, not a complete water kiosk	Commercialization of 3rd generation - Connecting funding partners with local implementation partners - Raising awareness of the technology - Suitability of the solution for tender processes in target areas

Table 2
Recognized main uncertainties across four stages of the Lifelink innovation process, structured according to the TCOS framework. Bolded text represents the uncertainties requiring particular attention in that stag.

Uncertainties	Ideation & conceptualization	Learning-based, product & business development	Scrutinized product & business development	Commercialization, multi-partnership model
Technological	Technological requirements Potential applications/technologies Transaction costs of SMS/mobile payment solutions	Expensive technologies Compatibility of Lifelink with various mobile operators, transaction costs Product and technological features Outsourced manufacturing	**Achieving required technology levels and passing gates of the development process** **Understanding the application and technologies** **Including correct product and technological features** **Simplicity of use and O&M**	Matching the needs and special requirements of customers State of infrastructure Lifelinks are based on
Commercial	**Lack of commercial experience** **Unknown customer segment** **Lack of market information** **Unbanked population** **Distance to local stakeholders** **Customer's willingness to pay for service / product**	**Sufficiency of water payments to increase sustainability, business model** **Commercial potential of Lifelink** **Price** **Transaction costs** **O&M model** **Reliability of partners**	Price Business model, servicing schemes and suppliers Preparing for sales, convincing customers Suitability for public tendering Few key players in the market (water sector in developing countries), strong role of donors and other development sector actors	**Commercialization and scaling up** **Competition** **Price-quality ratio** **Inclusion of Lifelink in procurement documents for grants and tendering processes** **Strong role of donors and other development sector actors** **Variability in water use from Lifelinks**
Organizational	Lack of experience: new organization (Lifelink), new technology, new market Lack of appropriate resources and capabilities	Role of Lifelink organization in the value chain Distance to Grundfos – understanding, position, organizational structures (e.g., for sales) Capability to develop a commercialized product	How and why Grundfos would bring to market Lifelink organization in a different 'space' than Grundfos, lack of understanding by Grundfos. Organizational structures for commercialization: Lifelink or Grundfos.	**Loss of agility under Grundfos** **Need for different processes and procedures due to completely different market segments and areas** **Need for different components: Grundfos approval times are long, sourcing from other places.**
Social	**Impact of local habits, traditions** **Local business practices** **Unbanked population** **Differing organizational logics (NGOs, local actors)** **Lack of understanding the environment** **Creating local buy-in**	**Suitability to local environment and capacities** **Local business practices** **Daily economics** **WASH understanding, habits, use of water** **Local buy-in** **Logistics and accessibility**	Social acceptability of Lifelink solutions Attitude towards water payments Lifelink as primary source of water	Site selection Acceptance of Lifelink solutions Willingness to pay for water WASH knowledge, water-use habits Lifelink as primary source of water Capacity of technical people

namely poor operation and maintenance of water distribution points, water monitoring and mismanagement of funds, and the use of diesel generators as a source of energy (Grundfos, 2018a). In Kenya, 41 % of the population lacks access to basic drinking water services (UNICEF and WHO, 2019), and sustainability of these services is often compromised due to the aforementioned challenges. Based on prior activities and the need for improved water services, Kenya was selected as the development environment and first market area for Lifelink.

Today, the Lifelink product family consist of two products—AQtap and AQpure. AQtap is a Water ATM, i.e. a water-dispensing unit for revenue collection and remote monitoring. In AQtap, mobile prepayment platforms are utilized for money transactions (Grundfos, 2016). AQpure is a UV-based modular water treatment system (Grundfos, 2018b). Our research focuses on the innovation process of the prepaid water ATM, although the two products partially share the same roots.

4. Water innovation process and uncertainties in resource-constrained environments

4.1. Critical stages for resource-constrained innovation process

The studied innovation process, including approach, key activities and qualities, are summarized with the help of chronological innovation stages in Table 1. Based on the literature and our case study, we recognized four distinctive stages in Lifelink's innovation process: (1) Ideation, conceptualization and early design, (2) Learning-based product and business development, (3) Scrutinized product and business development, and (4) Commercialization through a multi-partnership model. It is important to note that while the stages are described in a linear manner, all stages have involved an iteration between ideation, development activities, prototyping and testing.

The first years of the innovation process is characterized by an agile, iterative, learn-by-doing approach. The development team focused on discovering water services challenges, local requirements and market potential of an automated prepay water dispensing system. Knowledge and capabilities of local NGOs were utilized; but as challenges emerged, the Lifelink team increased its local presence and role and reformulated partnership strategy. After extensive field testing, a more scrutinized verification followed during the state-gate process. Simultaneously, the team's role in the field decreased, and strategic partnerships with international organizations were developed. When commercialized, Lifelink was integrated into the structures and process of the parent company (Grundfos). The innovation process is summarized in Table 1 and further elaborated in the Supplementary Material.

4.2. Innovation uncertainties across process stages

Innovation uncertainties of the studied water innovation process are analyzed with the help of the TCOS framework (see Section 3.1), and thus the following analysis focuses on the four uncertainty categories. In our analysis we have captured these four categories across the recognized process stages, establishing a matrix that combines the thematic uncertainty categories with temporal stages of the related innovation process.

During the early development stages, the social settings inflicted the majority of the uncertainties, as Lifelink/Grundfos did not have previous commercially oriented initiatives in the region, or an in-depth understanding of local practices. These directly translated into a range of commercial uncertainties, such as the overall feasibility of the concept, the ability to increase the sustainability of water services, and the reliability of partners. During the scrutinized development, technological aspects (such as solution features and achieving the required technology and quality levels) composed the main uncertainties. As the innovation entered markets, uncertainties emerged regarding commercial aspects, such as competition and succeeding in tender processes. In addition, organizational uncertainties emerged, as the needs of the Lifelink organization differ from the parent company under which the Lifelink organization was merged. The key technological, commercial, organizational and social uncertainties across all four stages are summarized in Table 2 and further elaborated in Supplementary Material.

4.3. Principles for managing innovation uncertainties in resource-constrained environments

Our data shows that innovation uncertainties, at least in water services sector, are often intertwined with each other and cut across several uncertainty categories. As a result, the uncertainties need to be reflected in the strategies managing such uncertainties. Based on the interviews on our case study, we have recognized the following cross-cutting principles for resource-constrained innovation management: (1) Versatility in R&D approaches, (2) Partnerships and networks to leverage complementary knowledge, resources and capabilities, and (3) Internal acceptability, trust and legitimacy. In the following, we use these three principles and related literature to structure the presentation of our findings. The text also has several references to the relevant quotes from Grundfos Lifelink representatives, summarised in Appendix B.

4.3.1. Versatility in R&D approaches

Versatility and flexibility in R&D approaches is visible in different stages of the innovation process. The approach for generating knowledge and developing the Lifelink solutions and business model evolved over time from an agile, learning-from-the-field approach into a more formal approach (see Appendix B, Q1). Such a dual approach proved to work well in managing the whole process and the varying uncertainties along the way, especially as commercial and social uncertainties dominated the development and required more effort than technological uncertainties. A small, agile and independent team in the beginning of the innovation process meant greater freedom to operate in the field, allowing the team to get to know the environment, market and related uncertainties (see Appendix B, Q2) and define the solution qualities and value proposition.

Working in a separate organizational unit outside the parent company enabled use of different organizational procedures, metrics and working culture (See Appendix B, Q3). In the early stages, learning was a key metric. But towards the more formal state-gate process, more traditional metrics for defining success, progression and continuation were introduced to complement the context-specific product and business requirements discovered in the earlier stages. Traditional metrics—such as reaching a specified standard unit price, warranty rates and sales at the reference price—are in place in the commercialization stage.

The more formal and traditional approach during the state-gate process proved to have its benefits. Component details were thoroughly assessed and specified. Bringing initially outsourced manufacturing, spare parts and software development in-house enabled an 80 % decrease in price. Simultaneously, the business case was refined and further developed. Since the commercialization, the loss of the original agility is seen as a challenge for Lifelink; and it was thus apprehended that the agility should be revived to respond to customer needs (see Appendix B, Q4). It seems that while the more traditional product development process within Grundfos enables the production of quality and well-defined outcomes, it decreases the possibility for quick alterations and testing. The separated organizational structure prior to state-gate seems to be effective in developing different variants, in customizing the solutions and in finding out the value propositions in resource-constrained contexts.

4.3.2. Partnerships and networks to leverage complementary knowledge, resources and capabilities

Selecting suitable partners, understanding the local setting and

overcoming the related uncertainties are considered crucial for resource-constrained innovation (Hahn and Gold, 2014; Van den waeyenberg and Hens, 2012; Webb et al., 2010). Our research data shows how the Lifelink organization had to commit and deploy its resources in order to get to know the new operational environment and model. This required finding the right people, organisations and networks to leverage, understanding market dynamics, and coping with the uncertainties. In different stages the partners differ, as different resources and capabilities are required. The initial stages required mobilizing the Lifelink team to the field and engaging specialists and organizations with specific knowledge in order to find suitable locations for prototyping, and to understand the business model requirements in the water sector (see Appendix B, Q5). In later stages, resources and capabilities of the parent company were leveraged to a greater degree, and responsibilities for the value chain activities were shared between the organizational entities.

During the piloting of the 1st and 2nd generation Lifelinks (Table 1), collaboration with NGOs and donor organizations (some of which had purchased a Lifelink solutions) served as important sources of market knowledge (see Appendix B, Q6). In the later stages, partnerships established with organizations having broader geographical scope or certain domain expertise enabled efficient scaling up (see Appendix B, Q7), and Grundfos/Lifelink could focus on their core competencies—innovation and R&D. For instance, the partnership with Ericsson—an international mobile communications company—enables connection to a mobile payment platform, which Ericsson negotiates with each country and/or each operator.

4.3.3. Internal acceptability, trust and legitimacy

Our research data indicates that internal acceptability and trust in Lifelink within Grundfos was critically important, as Lifelink was initiated through a separate organization. This was facilitated by the established tradition of internal business incubation in affiliated companies. Operating as a separate entity gave more freedom to the Lifelink organization, but it also meant that it had to communicate with the parent organization to justify its purpose and required resources (see Appendix B, Q8 and Q9). Due to the long-term commitment typically required in resource-constrained environments, internal support and trust are needed throughout the process, and not only when establishing new ventures. Still in the end of the studied process, the support and utilization of Grundfos' resources are important for Lifelink (see Appendix B, Q10).

Grundfos' way of organizing new ventures under separate organizational units can be seen as a demonstration of internal acceptability and trust, which also enabled the Lifelink organization to focus on topics that were not necessarily typical for Grundfos itself. Concurrently, this illustrates a way to manage uncertainties arising from these new ventures. The interviews indicate that Lifelink had a stronger emphasis on social and commercial aspects than on technological development, the traditional stronghold of Grundfos. The combination of freedom to operate and clear, long-term support by the parent company forms a key enabler for the water services innovation process. Our case study also shows how proximity—the ability to collaborate and leverage resources and capabilities of the parent organization—enables resource-constrained innovation.

5. Discussion and implications

5.1. A process-based view on innovation management in resource-constrained environments

This case study provides process-based insights into the diversity of uncertainties and related management strategies in a water services innovation. We utilized two main frameworks, the innovation stages and the TCOS framework (Section 3.1) as a mean to study uncertainties throughout the innovation process stages. We argue that this is particularly relevant in resource-constrained environments, where a variety of uncertainties (including diverse social uncertainties) are present across the innovation process.

Our case study suggests that successful innovation process in resource-constrained environments should be built upon an iterative and agile approach to enable constant learning from the environment. Western companies in particular should increase their local engagement in order to learn from the context and to incorporate these lessons into innovation development (Schuster and Holtbrügge, 2012; Zeschky et al., 2011, 2014). More traditional approaches, such as the state-gate process, proved beneficial in later process stages when scrutiny is required. The results, however, indicate that the innovation process should not evolve into an overly formal mode: agility is required even when innovations are commercialized in order to respond to varying needs and requirements in resource-constrained environments.

For water services innovation in resource-constrained environments, it is critical to understand the local environment, institutions and actors, including project implementers, water service providers and end-users. These aspects shape the solutions (including products and service and business models) to fit the needs and preferences of users, system operators and managers. Furthermore, the developed solutions need to correspond with the institutional and implementation requirements. Such an understanding is necessary, even when providing technologies and services to other parties such as governmental organizations and the private sector delivering water services.

Our results also clearly indicate the importance of partnerships and stakeholder collaboration in different innovation stages, and how requirements for partners vary in time, depending on the process stage and prevailing uncertainties. To our knowledge, previous studies have not recognized and discussed this temporal aspect of collaboration with partners. Partnerships, where national and international NGOs and development agencies have a key role, may be different from typical partnerships in more affluent markets (Hahn and Gold, 2014; Hietapuro and Halme, 2015; Mvulirwenande and Wehn, 2019; Rivera-Santos et al., 2012b; Webb et al., 2010). Utilizing partners and innovation intermediaries who understand field circumstances and local operations is an effective strategy, but shared objectives, mutual understanding with the partners and internal knowledge on the innovators side are required – aspects, that have also been recognized by other water innovation studies (Mvulirwenande and Wehn, 2019; Wehn and Montalvo, 2018a). Partnerships are not always easy to establish, and they can ignite further uncertainty (Mvulirwenande and Wehn, 2019; Porter and Birdi, 2018). However, knowledgeable partners, which can differ between process stages, and informal networks help in understanding and managing various types of uncertainties as well as enable the use of external resources and capabilities.

Our study also highlights the importance of a reformulation of strategies during the innovation process. The same strategies and approaches for product and business development do not necessarily fit into the different stages of the process, as the requirements and focus of the processes change. For instance, in the beginning the need for market-related information is high; whilst in the later stages, the focus shifts to engineering the products to fit the developed value proposition. These findings highlight the ways in which organizational capabilities required in developing markets differ from more traditional innovation activities focused on affluent markets (Van den waeyenberg and Hens, 2012; Webb et al., 2010; Zeschky et al., 2011). This necessitates agility in the ways of working, support from the top management as well as collaboration with non-traditional partners along the entire value chain. In contrast to innovating for affluent markets, our case shows the time-consuming nature of getting to know resource-constrained environments and finding the right partners, as well as the agility needed for innovation.

5.2. Methodological implications

The key methodological novelty of our study is the application of the TCOS framework to study the different types of uncertainties and to recognize related management principles, and to do this through the main stages of a water innovation process in a resource-constrained environment. Our findings indicate that the different innovation process stages face different types of uncertainties and that they are commonly intertwined. Our analysis shows that internal legitimacy (see Section 4.3) plays a crucial role in the successful development of resource-constrained innovation, suggesting that future studies utilizing the TCOS framework could also consider internal legitimacy in addition to the cognitive and socio-political legitimacy discussed by Hall et al. (2014a, 2012, 2011).

Our case underlines the importance of acknowledging and understanding social uncertainties throughout the process. Our findings show how the social setting can inflict various other types of uncertainties, requiring companies to find new ways and strategies to understand and manage these challenges. However, due to the intertwined nature of uncertainties, the strategies should enable the management of various uncertainties at the same time, although these strategies can differ between stages. These observations support the use of the TCOS framework—combined with the innovation process (temporal dimension)—as an analytical tool in understanding resource-constrained innovation.

Previous studies have emphasized the meaning of partnerships for innovation (Hahn and Gold, 2014; Hietapuro and Halme, 2015; Ray and Ray, 2011; Wehn and Montalvo, 2018a). Our study provides a new understanding of the variety and role of partners throughout the temporal dimension. The use of different methodologies and perspectives might be required between process stages in order to reach a comprehensive understanding of partnerships.

5.3. Managerial implications

There are three key managerial implications from our study: (1) Understanding local context, available resources and capabilities as well as the targeted sector, (2) Commitment to internal competence development, and (3) Selection of partners in different stages to access complementary knowledge, resources, capabilities and networks.

To tap into resource-constrained customer segments, local development and manufacturing in low-cost environments have been regarded as key means to bring costs down and answer to the needs and desires of consumers (Winterhalter et al., 2015; Zeschky et al., 2011). However, to our knowledge, these studies have only focused on industrial manufacturing resources and capabilities in Asia, and not in Africa. In our case, the technologies are not manufactured locally in Kenya, as the manufacturing facilities are centralized in selected existing locations to ensure quality and cost-efficiency. We argue that existing facilities and required investments, together with the quantity and quality of manufactured goods, affect the overall applicability and potential of cost savings through local manufacturing. The principle of local manufacturing is noble, but not applicable in all contexts and sectors. For instance, in many parts of Africa, the history and capabilities for industrial manufacturing differ greatly from China and India. Furthermore, the market for low-cost manufacturing is currently very competitive. Importance of understanding the local context and sector are further elaborated in Supplementary Material and Sections 4 and 5.1.

Innovating organizations need to themselves hold relevant knowledge, resources and capabilities, instead of relying solely on external support and partners. When entering new market areas, organizations need to be committed to develop the competencies, skills and capabilities of staff in order to understand, develop and manage the innovation process. Partnerships in different stages of the innovation process can serve for different purposes, and in our case study multiple partners are required. Complementary role of partners is further elaborated in Section 4.3.2.

6. Conclusions

Our case study provides insights into the specific characteristics and uncertainties of water innovation process in resource-constrained environments. Examples of resource-constrained innovations from a variety of sectors exist (Gebauer et al., 2017; Gebauer and Saul, 2014; Marconatto et al., 2016; Mvulirwenande and Wehn, 2019; Winterhalter et al., 2017), but there is no consistent knowledge on how sector-specific characteristics and uncertainties in these environments influence both the outcomes of the innovation process and the process itself. For western companies, resource-constrained areas often present new markets, and understanding the socio-economic and political environment—and related uncertainties—is crucial for success.

This article provides new understanding of the complexity and time-consuming nature of developing and managing water innovation in resource-constrained environments. Scrutiny is required in certain stages of the process, especially in defining the final technological configuration; on this front, the structured state-gate process proved its power, to complement the more agile approach that was used in particular during the early stages of the innovation process. The results indicate the significance of social uncertainties throughout all stages of the innovation process, including the ways they evolve, impact and relate to the other types of uncertainties. The entire innovation process and related innovation management strategy development can thus be seen as learning-based processes, where new knowledge is co-created through engagement with other actors. For this to be successful, it is naturally important to identify right partners for different stages, but also to understand and appreciate the different ways of working to make the most of the collaboration.

Based on our analysis, we argue for a holistic design of innovation management strategies to overcome uncertainties in different innovation process stages. The strong involvement of the public sector, donors and other development sector organizations has shaped the water sector in developing regions, and private sector actors need to consider this when entering these markets. Combining the vast sectoral knowledge held by public and development sector actors with the additional competencies of the private sector has the potential to create more efficient water services. While the SDGs also emphasize public-private collaboration, further enabling policies are still required for such collaboration really to be effective. It is important to recognize that innovation in such environments is also a highly sensitive and politicized field, with differing interests and tensions (Pansera and Owen, 2018). The sustainability implications of developed products and services need to be therefore assessed in a transparent manner.

We suggest that future studies on water innovation in Africa should pay careful attention to social uncertainties and their linkages to other uncertainties throughout the innovation process. Only a nuanced understanding of the key innovation stages and the interconnected uncertainties enables successful innovation development and management. More thorough understanding of the most viable ways for partner selection across the innovation process is also needed. Combinations of different innovation development approaches, such as agile and state-gate processes, provide another interesting arena for future studies.

Author contributions

Anne M.J. Hyvärinen had the main responsibility for the research design, collecting and analysing the data and writing the article. Jarkko Levänen and Marko Keskinen helped in designing the research and contributed particularly to writing the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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An earlier version of the research was presented at the R&D Management Conference 2017 in Leuven, Belgium.

Appendix A. List of data utilized in this article

Table A1

Table A1
Interviewed key informants, visited sites and other data.

DATA SOURCE	DURATION	DATA TYPE
Managing Director, Grundfos Lifelink	60 minutes	Recorded semi-structured Skype interview
Global Partnerships Director, Grundfos Lifelink	60 minutes	Recorded semi-structured Skype interview
Global Product Manager, Grundfos	60 + 30 minutes	Recorded semi-structured Skype interviews
Senior Technology Director, Grundfos	80 minutes	Recorded semi-structured interview
Field Technician, Grundfos Lifelink Kenya	120 minutes	Recorded semi-structured interview
Field Technician, Grundfos Lifelink	30 minutes	Recorded semi-structured interview
Urban water utility, Kenya, Regional Officer. 3rd generation Lifelink	45 + 30 minutes	Field observations and notes on discussions
Urban water utility, Kenya, Regional Manager & Social Worker	60 minutes	Recorded semi-structured interview
Water Committee member in Athiriver. Operator of 1 st generation Lifelink	60 minutes	Field observations and notes on discussions
Head of local Water Committee in Mwambathaana. Operator of 2nd generation Lifelink	90 minutes	Field observations and notes on discussions
Administrative Manager, Grundfos Lifelink Kenya	30 minutes	Notes on discussion
Grundfos annual reports 2008–2016, Grundfos journals 2012–2016, Grundfos website, Case study reports, Project reports, Research and consultant reports, Blog posts, News, Articles, Conference presentations and papers		Documentary material

Appendix B. Quotes from Grundfos Lifelink representatives

Q1: The Lifelink Managing Director noted the remarkable difference between the two R&D approaches: '*we worked like day and night*'.

Q2: The importance of beginning the Lifelink innovation process with a small, agile team is described by the Global Product Manager: '*…taking the right R&D approach at the right point of time. Starting with, when you don't know, you have a lot of uncertainties and a lot of missing knowledge, instead of trying to make a big development and plan a lot, you take a very iterative learning-based approach. We could have started with a big development project, and then we wouldn't have had any doubts with the prototypes…but it probably would not have been a product that was matching requirements and the needs of the customers*'.

Q3: The Lifelink Managing Director describes the early stage metrics: '*Every year we had to prove some new points to be allowed to go for a second round. So learning per dollars spent, it was quite important in these early days*'.

Q4: As described by the Lifelink Managing Director: '*We would need to get that agility back so we can work very fast with customers when they have special requirements*'.

Q5: Commitment, presence and learning by the Lifelink team is described by the Global Product Manager: *'They also spent quite a bit of time in the field, really being out there with their pilots and seeing how would it…how was the user experience around them. How did the technologies fit to real life, and learning from that'*.

Q6: The Global Partnerships Director explains the role of other organizations as knowledge sources: *'We collect some data by ourselves; but the NGOs on the ground also have a lot of data. When we started developing the next generation, we had a lot of consultation with the NGOs, even with the World Bank representatives, with the government officials, and the utilities to make sure that the features we are building respond to the markets'*.

Q7: The Lifelink Managing Director explains partnerships with globally operating organizations: *'We do not work with the NGOs country-by-country. We work with global framework agreements. Then it is up to the NGO to discuss country-by-country with their own people whether or not this technology should be embraced. We now have five of these major framework agreements with some of the biggest NGOs of the world'*.

Q8: The Lifelink Managing Director describes communication with Grundfos: *'We have been fighting internally at Grundfos to make sure that you can say the opportunities are being understood in the right way and where Lifelink should belong within Grundfos'*.

Q9: The Lifelink Managing Director describes the resources available from Lifelink from Grundfos: '*Every time that I [the Lifelink Managing Director] have raised my voice or needed anything, Grundfos has given it to me'*.

Q10: The Lifelink Managing Director talks about the support and resources from Grundfos: '*I'm so privileged that I actually control the people in the sales companies [of Grundfos]. You can say they have a dual responsibility or dual reporting where they also report to the Grundfos GM. But ultimately [for Lifelink], it is my responsibility and I can make the call*'.

Appendix C. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2020.07.007.

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