Science and Public Policy, 47(3), 2020, 333–347
doi: 10.1093/scipol/scaa015
Advance Access Publication Date: 19 February 2020
Article

Innovation system formation in international development cooperation: The role of intermediaries in urban sanitation

Mara J. van Welie[1,2], Wouter P.C. Boon [2,*] and Bernhard Truffer[1,2]

[1]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, Dübendorf CH-8600, Switzerland and [2]Faculty of Geosciences, Utrecht University, Heidelberglaan 2, NL-3584 CS Utrecht, The Netherlands

*Corresponding author. E-mail: w.p.c.boon@uu.nl

Abstract

The transformation of urban basic service sectors towards more sustainability is one of the 'grand challenges' for public policy, globally. A particular urgent problem is the provision of sanitation in cities in low-income countries. The globally dominant centralised sewerage approach has proven incapable to reach many of the urban poor. Recently, an increasing number of actors in international development cooperation has started to develop alternative *safely managed non-grid approaches.* We approach their efforts as an emerging 'global innovation system' and investigate how its development can be supported by systemic intermediaries. We analyse the activities of the 'Sustainable Sanitation Alliance', an international network that coordinates activities in the sanitation sector and thereby supports this innovation system. The findings show how demand ing it is to fulfil an intermediary role in a global innovation system, because of the need to consider system processes at different scales, in each phase of system building.

Key words: innovation policy; societal challenges; innovation intermediaries; systemic intermediaries; global innovation systems; urban sanitation

1. Introduction

Transforming urban basic service sectors towards more sustainability is one of the 'grand challenges' for public policy globally. A particularly pressing area for the improvement of life conditions are informal settlements in cities of low-income countries. Rapid urbanisation and insecure tenure rights lead to a general under-provision of basic services. Sanitation in particular has been a sector where not much improvement has been achieved over the last decades, despite myriads of initiatives by donors, non-governmental organizations (NGOs), private, and public actors. Over the years, it became more and more apparent that conventional centralised sewerage systems are confronted with major problems in informal settlements and the situation is unlikely to change anytime soon. Therefore, international donors, the private sector, development agencies, and research institutes have started to experiment with a wide variety of technologies and business models around innovative non-grid systems. However, these initiatives have not yet gained the same legitimation as the globally dominant centralised sewerage approach. We analyse the conditions for these alternative systems to mature while addressing the grand societal challenge of sanitation by framing these initiatives as part and parcel of an emerging (global) technological innovation system, and ask how intermediation can support innovation system building activities in a transnational context in different phases.

For many years, international development cooperation[1] attempted providing sanitation for all residents in cities of low-income countries. This has been difficult because of a lack of city-wide sanitation planning, large inequalities between neighbourhoods, rapidly expand ing informal settlements where there are issues with land tenure, low education levels, and institutional and political challenges (LeteMa et al. 2014; Okurut and Charles 2014; Andersson et al. 2016; Ramôa et al. 2016). Two approaches have dominated most sanitation projects in international development cooperation: in city centres *grid* approaches, based on waterborne centralised sewerage systems became widely adopted. Rural areas and urban informal settlements saw the promotion of several forms of traditional *non-grid* options, mostly focusing on the provision of toilets like pit latrines. The two approaches, however, did not result in hygienic and affordable sanitation services for a majority of citizens. In cities of low-income countries, sewerage systems are mostly restricted to city centres and high-income neighbourhoods and these infrastructures hardly ever reach the urban poor, due to a lack of financial resources, water scarcity, and absence of necessary skills

(Esrey et al. 1998; Black and Fawcett 2008; Lüthi et al. 2010; Jewitt 2011; Strand e et al. 2014; Andersson et al. 2016; Reymond et al. 2016). At the same time, traditional non-grid options notoriously lead to serious environmental and health problems in cities: latrines contaminate groundwater sources, are unhygienic when they fill-up and overflow, and the emptied sludge is often disposed without appropriate treatment (Esrey et al. 1998; Koné 2010; Strand e et al. 2014).

In the last years, the shortcomings of these two approaches have been increasingly recognised in international development cooperation, and a new technological field took shape that we label here as the *safely managed non-grid sanitation* (*SaMaNG*) approach. It aims at providing hygienic services to users while enabling safe management of the waste, to prevent health hazards for the operators and contamination of the environment. Until today, SaMaNG has not developed into a fully spelled-out sustainable sanitation approach yet. It still encompasses a wide variety of technologies, which are promoted by different actors and rely on various supporting infrastructures and institutional arrangements. This leads to a diversity of service offerings and business models that depend on continuous support by international donors and limited city-wide implementation so far. Therefore, SaMaNG represents a promising and emerging, yet not fully-developed field that still has to mature to provide safe and affordable sanitation services.

We propose to analyse the conditions of successful development of this field by approaching it as an emerging (technological) innovation system (TIS). A TIS consists of different types of actors that interact in networks and define/shape institutions to contribute to the generation, diffusion, and utilisation of a new technology or a new product (Carlsson and Stankiewicz 1991; Markard and Truffer 2008). For an innovation system to function well, processes of knowledge creation, market formation, resource mobilisation, and legitimation need to be developed in a balanced way through an interplay of strategies by different actors (Hekkert et al. 2007; Bergek et al. 2008). TIS research has repeatedly shown that innovation success depends on the existence of appropriate intermediaries, who identify lacking capabilities, help to overcome coordination failures, and work on the removal of institutional barriers (van Lente et al. 2003; Klerkx and Leeuwis 2009).

Besides these structural and functional characterisations, innovation systems research elaborated on how time and space intervene as core variables to explain innovation success. In dynamic terms, it is well established that innovation systems develop in different phases, namely a formative, growth, and maturation phase (Bergek et al. 2008; Markard 2018). Regarding the spatial characteristics, innovation system research was traditionally restricted to developments occurring in specific countries or regions (Cooke et al. 1997; Asheim and Gertler 2005; Lundvall 2007). More recently, however, scholars have criticised this containerised view of space (Coenen et al. 2012) and formulated frameworks for addressing multi-scalar relationships in innovation systems and ranging all the way up to the global level, as evinced by the notion of 'global innovation systems' (Binz and Truffer 2017).

Taking the dynamic and spatial perspectives into account, tackling the sanitation challenge can be understood as a need for managing an international innovation system that provides solutions to a global societal challenge. The innovation system therefore becomes particularly conditioned by public policy interventions, or as some authors have called it, it is a case of a 'mission-oriented' innovation system (Boon and Edler 2018; Mazzucato 2018).

In a transnational setting, intermediary activities might be even more challenging because the wide variety of geographical contexts may require different solutions, which hamper the alignment of visions among different actors. In this article, we analyse the formation of a global innovation system in the field of SaMaNG sanitation by focussing on the work of a globally operating intermediary. We aim to contribute to the literature by increasing our understand ing of the potential role of intermediaries in supporting system-building activities in a transnational context, towards overcoming persistent global societal challenges. We specifically aim to analyse the following aspects: (1) the development of TIS functions at different spatial scales; (2) the intermediary activities in different phases of innovation system building; (3) the support of multi-scalar relationships (structural couplings) by the intermediary.

We conduct an in-depth case study of a specific international intermediary in the SaMaNG field: the Sustainable Sanitation Alliance (SuSanA). SuSanA was established in 2007. Its founders were convinced that for the further establishment of sustainable sanitation approaches, the rather large number of isolated initiatives in the field had to be better coordinated, especially with regard to knowledge generation, resource mobilisation, and technology legitimation for non-grid alternatives. SuSanA was set up as a network of member organisations (including research institutes, private sector, NGOs, and development agencies) and individuals who wanted to contribute to achieving the Millennium Development Goal by promoting sanitation systems that take all aspects of sustainability into consideration (SuSanA 2008). The network brought together actors from all over the world by organising meetings, webinars, and by providing a website and online discussion forum. We reconstruct how the SaMaNG innovation system developed since the 1970s, and identify how SuSanA supported all sorts of weaknesses in innovation performance over the last decade, based on twenty-one in-depth expert interviews and extensive secondary data.

The article is organised as follows. In the next section, we introduce the innovation studies literature in order to develop a conceptual framework to assess the role of intermediaries in mission-oriented, transnational innovation systems. In the third section, the case and data sources are explained. Section four elaborates the results of our study. We provide an assessment of the developments in the SaMaNG field, which leads to the current challenges that the innovation system is confronted with. Particular emphasis is on the specific contribution of SuSanA to these developments. In section five, we discuss how the structure and activities of SuSanA might have to be adapted in the future to accommodate for the changing needs of a maturing innovation system. The conclusions elaborate general requirements that can be derived for intermediaries that aim at supporting transnational, mission-oriented innovation systems in the longer run.

2. Theoretical background

In order to gain insights into the role of intermediaries in system building in a transnational context, we build on several conceptual insights from innovation system literature.

2.1 Global societal challenges and innovation systems

To solve the global sanitation problem, there is a need for all sorts of technological and social innovations. In the academic literature, there has been growing interest in how to formulate innovation policies that are able to tackle these grand societal challenges

(Kuhlmann and Rip 2018; Robinson and Mazzucato 2018). We join them in using the term 'mission-oriented' to specify this particular focus on solving global societal challenges. The innovation literature distinguishes two types of mission-oriented policies: a 'type 1' use of missions focused on technological challenges such as putting a man on the moon, and a 'type 2' of complex missions focused on solving global societal challenges (Foray et al. 2012; Mazzucato 2018; Robinson and Mazzucato 2018). We focus on type 2 missions that others have similarly described as mission-oriented innovation policy centred on complex (wicked) societal problems, focused on long-term goals, and having a transformative character (Schot and Steinmueller 2018). As for solutions we do not focus solely on 'big science' or single technological fixes, but strive for a wider variety of interrelated innovations (Wanzenböck et al. 2018) developed and championed by a diverse set of actors, including demand -side actors (Boon and Edler 2018). In this article, we start from the premise that type 2 missions call for a systemic approach: rather than stimulating a focal technology and set of actors, multiple technologies, approaches, and actors are necessary to address the challenge, at least in the first stages of development.

The literature on innovation systems takes a systemic perspective on the interaction of actors in networks and the role of institutional arrangements in the promotion of innovations (Weber and Truffer 2017). Innovation is broader than just developing new technologies, but also applies to new services, management arrangements, and business models, and the adaptation to, or change of institutional context conditions. Moreover, innovation happens as a result of the interplay of actors (e.g. firms, government, research institutes, NGOs, etc.) situated in networks and contextualised by institutions (e.g. formal rules and regulations as well as norms and values). Innovation system studies have introduced notions and concepts to better understand the emergence and implementation of innovations. Furthermore, innovation systems have been applied to development contexts in order to analyse persistent development problems and the role of (technological) innovations therein (Blum et al. 2015; Kebede and Mitsufuji 2017; Kriechbaum et al. 2018; Sixt et al. 2018; van Welie et al. 2019) and are argued to be relevant new perspectives for development scholarship (Romijn and Caniels 2011).

A specific type of innovation system focuses on the emergence of one (or a related set of) new technologies and is called the TIS. A TIS 'is a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilisation of variants of a new technology and /or a new product' (Markard and Truffer 2008: 611). Within TIS several system processes should operate in order for the system to perform well: knowledge production and diffusion, resource mobilisation, market formation, legitimation creation, guidance of search, and entrepreneurial activities (Hekkert et al. 2007; Bergek et al. 2008). System processes that are insufficiently developed indicate need for action on the side of policy makers or other actors wanting to support the innovation. Additionally, one can identify 'system weakness/failures' in an innovation system in the form of coordination, institutional, or capability deficits, that need to be corrected in order for an innovation to develop successfully (Klein Woolthuis et al. 2005). Innovation systems develop in stages (Suurs and Hekkert 2009): in the formative phase, they often consist of loosely coupled initiatives by diverse actors that pursue a wide variety of alternative designs. In the subsequent growth phase, the number and intensity of intermediary activities tend to increase, networks get densified and more and more specific institutions emerge. This leads to the formation of dominant designs and increasingly stand ardised markets. In a third stage of maturation, knowledge, resources, legitimacy, and markets further grow and align until the point where they converge into a widely accepted new paradigm for the field (Bergek et al. 2008; Markard 2018). Recent TIS studies have started to extend their focus from single technologies to entire socio-technical systems (Sandén and Hillman 2011; Bergek et al. 2015; van Welie et al. 2019) and this has prepared the ground for analysing technological innovation systems that explicitly address grand societal challenges (Frenken 2017).

Grand societal challenges typically span across a wide range of geographical regions. The analysis of such processes should explicitly address innovation dynamics occurring at different scales (Coenen et al. 2012). To take spatial scales and boundaries into account, Binz and Truffer (2017) propose a conceptualisation of transnational TISs as being constituted of different functional subsystems that can be attributed to specific geographical scales: transitional, regional, national, etc. A 'global innovation system' performs well, if the functional developments happening in different subsystems are effectively coupled so that a coherent innovation trajectory develops (Binz and Truffer 2017). These 'structural couplings' are shared elements (actors, networks, institutions, technologies) between different subsystems of a global TIS or between them and specific contexts (Bergek et al. 2015). They can be formed by partnerships, transnational cooperations, academic networks, or international trade fairs. Structural couplings can in particular be facilitated by intermediary organisations.

2.2 Intermediaries in innovation systems

Intermediary organisations have been identified as key actors in the innovation literature since the 1990s. Early studies focused on knowledge brokering intermediaries in the context of innovation management and technological development (e.g. Bessant and Rush 1995). In this line, Howells (2006) defined the term 'innovation intermediary' as an organisation or network that acts as a broker or agent in any aspect of the innovation process between two or more parties (Howells 2006). Examples of intermediaries are industry associations (Watkins et al. 2015), user organisations or product development partnerships in the health sector (Moran et al. 2010; Boon et al. 2011), innovation platforms in agriculture (Lamers et al. 2017), NGOs and consultancies in the energy sector (Bush et al. 2017), or transition intermediaries (Kivimaa et al. 2018).

In the early 2000s, the role of intermediaries in the context of innovation systems was signposted by van Lente et al. (2003). These 'systemic intermediaries' enable cooperation between different types of actors for successful innovation. They can close cognitive, normative, or managerial gaps that can hamper the proper functioning of an innovation system (Klerkx and Leeuwis 2009). Intermediary organisations might for example 'connect, translate and facilitate flows of knowledge' (van Lente et al. 2003: 248). Especially in the context of low-income countries, maturing innovation systems are often characterised by several system weaknesses, for example, capacity and coordination deficits (Shou and Intarakumnerd 2013; Klerkx et al. 2015; Tigabu et al. 2015; Kriechbaum et al. 2018). Strengthening intermediaries could improve the functioning of innovation systems in these contexts, for example, towards more coordinated innovation processes (Kilelu et al. 2011; Szogs et al. 2011; Intarakumnerd and Chaoroenporn 2013; Klerkx et al. 2015).

In the literature, several lists of intermediary functions have been proposed (see e.g. Howells 2006; Boon et al. 2011; Kivimaa 2014).

Systemic intermediaries typically pursue three key intermediary functions in innovation and transition processes: '1) *articulation of options and demand* , which includes the stimulation of technological variety and the search for possible applications. This also includes of the awareness of possible futures; 2) *alignment of actors and possibilities* (emphasis in original), by initiating and strengthening linkages between the various parts of the innovation system. It includes the building and sustaining of networks and the facilitation of interfaces; 3) *support of learning processes*, by enhancing feedback mechanism and by stimulating experiments and mutual adaptations' (van Lente et al. 2003: 256). Distinct key activities and processes in the various phases of innovation system development suggest different roles for systemic intermediaries over time (van Lente et al. 2003).

The literature has so far mainly focused on intermediaries that act in innovation systems that are clearly demarcated in time and space. Recently, Kivimaa and colleagues defined intermediaries that contribute to sustainable transitions, presented an agenda for future research on this topic (Kivimaa et al. 2018) and showed how the roles of transition intermediaries change during the different phases of transitions (Kivimaa et al. 2019). The latter paper showed that systemic intermediaries are relevant to all transition phases. They articulate visions and a variety of technological options in the early stages as neutral, unbiased facilitator, and broker, whereas they later aim to engage in market creation and creating new institutions. Furthermore, a few recent studies have discussed intermediaries in innovation systems in multi-scalar contexts (Lamers et al. 2017; Lukkarinen et al. 2018). Scholars that have analysed cross-boundary intermediation so far, have identified that institutional and cultural gaps require extra attention in brokering global collaborations for innovation (Ma et al. 2014; Klerkx and Guimón 2017). Additionally, research on partnerships for development showed that the role of intermediaries often goes beyond simple brokerage and can take the form of convener, mediator, and learning catalyst (Stadtler and Probst 2012). However, still not much is known about how intermediaries connect subsystems in global innovation systems (Binz and Truffer 2017: 1295). In this article, we seek to better understand the potential role of intermediaries in supporting system building activities in a transnational context, towards overcoming a persistent global societal challenge. This means that we explicitly consider intermediation across different spatial scales, and discuss the challenges and lifecycle of such intermediaries in different phases of innovation system building.

2.3 Conceptual framework

We focus on networks that, just like individual actors or organisations, can act as systemic intermediaries, when they have a certain agency and organisational core with which they facilitate the three systemic intermediary functions of articulation, alignment, and learning (van Lente et al. 2003; Musiolik et al. 2012). To answer the research questions, we analyse the contribution of a specific intermediary to overall system development by assessing its impact on the core innovation system processes in subsystems at different geographical scales and across time. Our analytical framework builds on the following two conceptual perspectives.

First, we elaborate how the three key functions of a systemic intermediary as identified by van Lente et al. (2003) contribute to the innovation system processes (knowledge production and diffusion, resource mobilisation, market formation, legitimation creation, guidance of the search, and entrepreneurial activities, see Hekkert et al. 2007; Bergek et al. 2008) We do that by building on a recent proposal by Lukkarinen et al. (2018) who specify how a broader set of intermediary activities (based on Kivimaa (2014)) can be classified under the system processes. We sort this broader set of intermediary activities into the three key intermediary functions. We then used Lukkarinen et al. (2018) to add the innovation system processes to the activities sorted under the three key intermediary functions. This leads to the following proposal:

1. *Articulation*: articulation of needs, expectations, and requirements; advancement of sustainability aims; strategy development; policy implementation (*guidance of search*); acceleration of the application and commercialisation of new technologies (*market formation*).
2. *Alignment*: creation and facilitation of new networks, managing financial resources, identification and management of human resource needs (*resource mobilisation*); gatekeeping and brokering, configuring and aligning interests (*legitimation*).
3. *Learning*: knowledge gathering, processing, generation, and combination; communication and dissemination of knowledge; education and training; provision of advice and support (*knowledge development and diffusion*); prototyping and piloting, investment in new businesses (*entrepreneurial activities*); technology assessment and evaluation (*legitimation*).

Based on insights from previous research on cross-boundary intermediation, we expect that in the process of *articulation* extra reflection is needed on the choices that are made, to make sure that the strategic interests of all partners in different places and countries are represented (Klerkx and Guimón 2017). In *alignment* processes simple brokerage may not be enough in transnational contexts, so intermediation efforts to overcome institutional and cultural gaps between different institutional environments are needed (Stadtler and Probst 2012; Ma et al. 2014; Pfotenhauer et al. 2016; Klerkx and Guimón 2017). In *learning* processes for development, there is a need for social/network ties to gather and disseminate knowledge, and these between partners can also be used to promote context-dependent learning processes (Stadtler and Probst 2012). Cross-boundary learning might also ask or new types of learning, such as e-learning (Pfotenhauer et al. 2016).

Secondly, when addressing grand societal challenges, we expect that intermediation has to play a different role in different phases, and has to address processes across different spatial scales. We thus have to take into consideration that the needs for intermediation change over the different maturation phases of an innovation system (van Lente et al. 2003). Furthermore, we frame the innovation processes as part of a 'global innovation system' (Binz and Truffer 2017). This implies to consider the existence of potential subsystems emerging in various countries or regions as well as the interlinkages between them through adequate structural couplings. We thus propose to extend the conventional understand ing of system intermediation focused on a TIS in a specific country or region, by a geographical dimension. Intermediaries therefore have to not only contribute to innovation system processes in one specific subsystem, but also to the creation or strengthening of structural couplings, as an additional process to ensure system maturation and innovation success (e.g. by means of discussion platforms, and in establishing partnerships between actors from otherwise isolated regions). This means that the intermediary function of 'alignment' should be expand ed to include contributions to coordination among different spatial subsystems as well as the creation and strengthening of structural couplings between them.

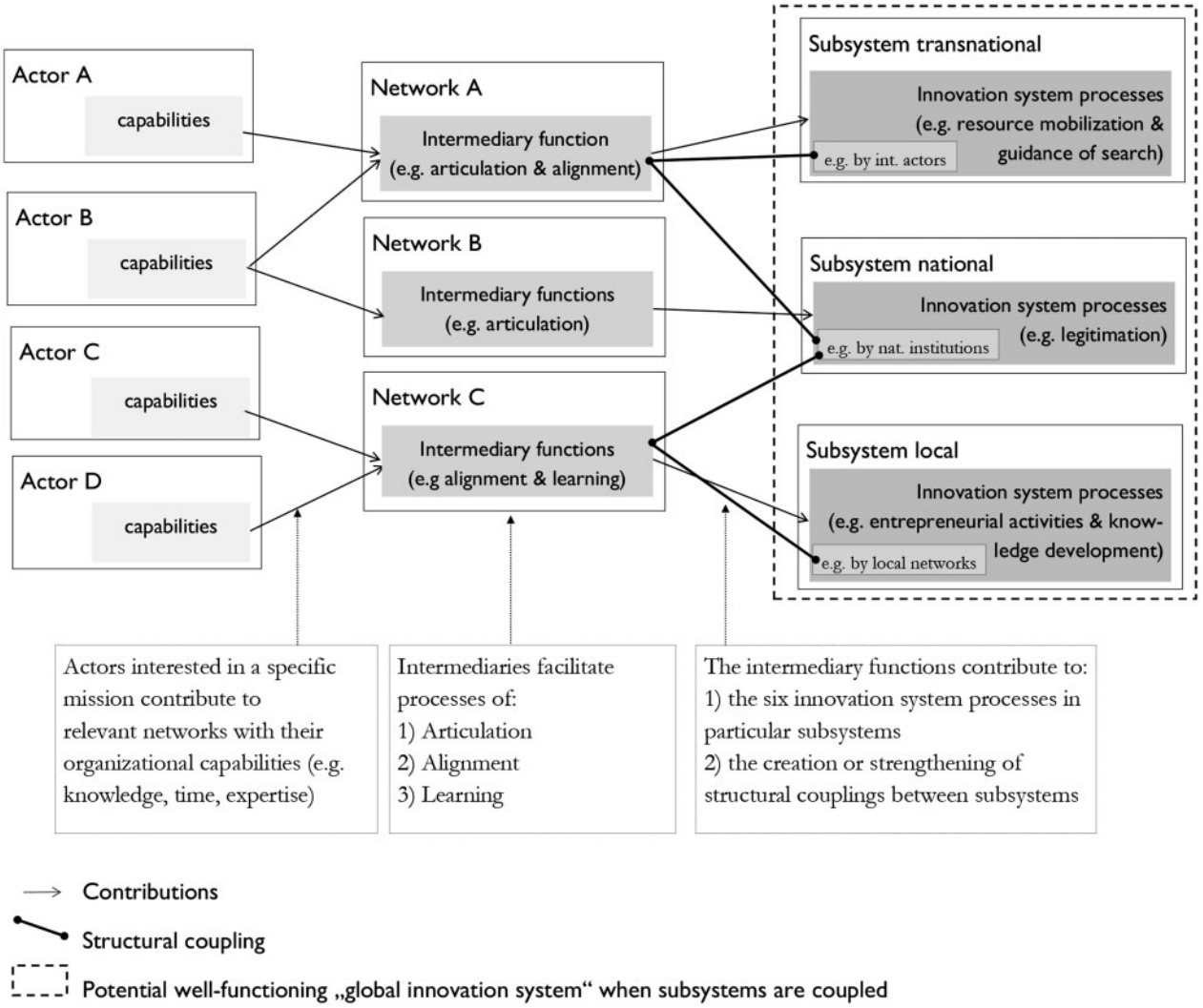

Figure 1. Analytical framework combines insights from van Lente et al. (2003), Musiolik et al. (2012), Binz and Truffer (2017) and Lukkarinen et al. (2018).

This leads to our analytical framework as illustrated in Fig. 1. We identify how actors (left side of Fig. 1, e.g. international development agencies, donors, NGOs, states, research institutes, community groups, etc.) can team up in networks to fulfil the three key intermediary functions for the development and maturation of a global innovation system (middle of Fig. 1). We further propose to analyse how intermediary functions contribute to different system processes in different phases, in specific subsystems at particular spatial scales (right side of Fig. 1). Finally, we identify how intermediaries contribute to the creation or strengthening of structural couplings between the different subsystems (thick lines showing that intermediary activities connect actors, institutions, and networks at different spatial scales in the boxes at the right side of Fig. 1).

3. Case selection, data, and method

We conducted a case study of the 'SuSanA' in the period 2007–17 (Yin 2014) to gain in-depth insights about the role of an intermediary in an innovation system (Yin 2014). SuSanA is a network that facilitates and coordinates sanitation activities in international development cooperation, aiming to contribute to achieving the SDGs and especially the sanitation targets of SDG6. It was founded in 2007, by several key individuals from Western and Northern-European development agencies and research institutes. It was established to raise awareness, promote, and create a vision on sustainable sanitation, address the lack of coordination in the sanitation sector, and strengthen the sector's capabilities. It has grown into a coordination and knowledge sharing platform, organiser and supporter of meetings and conferences, and takes a role in advocacy. SuSanA has currently 330 partner organisations and about 10,000 individual members (SuSanA 2019). It has thirteen thematic working groups and a 'core group' of experts that takes operational decisions for the network. The SuSanA secretariat, based at GIZ,[2] facilitates and coordinates the organisation and outputs of the SuSanA network.

SuSanA is a unique case in the context of sanitation because there has been no other similar network and knowledge platform that has been solely focused on sanitation in the last decade; and it is a typical case in the sense that it represents an intermediary network that connects multiple scales in international development (comparable to networks in global health, agricultural research for development, or diffusion of renewable energy technologies, see Boon et al. 2011; Platonova 2013; Lamers et al. 2017).

The case study is based on data from twenty-one in-depth, semi-structured interviews conducted with experts between February and October 2018 (see Supplementary Appendix). The experts were identified using snowball sampling. The interviews lasted between 30 and 120 min. All interviews were recorded and were either transcribed or extensive summaries were written. The interviews were triangulated with secondary data, such as scientific literature, organisational reports, books, and webpages, to increase validity (Cresswell 2009). The extensive information about SuSanA available on the network's website and the forum was also taken into account. Among others, documents produced by SuSanA (e.g. vision, factsheets, etc.), minutes and agendas of SuSanA meetings, and recordings of meetings and webinars were used. Lastly, the secretariat shared basic data on their partners, including the year in which the organisations became a SuSanA partner. A list of the most important books, reports, and webpages used for the case study is provided in the Supplementary Appendix.

We analysed the data in several steps. First, we created an overview of SuSanA's characteristics and history, as well as of the broader historical sectoral developments. This included ordering and linking key events and actors along a time-line. Secondly, we created an overview of the main actors in the emerging SaMaNG innovation system. Thirdly, we used the intermediary functions and innovations system processes to analyse the innovation developments, and distinguished development phases in which different intermediary and innovation system processes became dominant. Finally, we wrote a narrative and created a summarising figure for the development of SaMaNG and SuSanA, based on the previous steps. The narrative was checked by two experts to validate the interpretation of the data.

4. Results

In this section we present the evolution of urban sanitation in international development cooperation since the 1970s until today, and explain how new SaMaNG approaches have developed. We then analyse the corresponding activities in the last decade as an emerging innovation system, and identify the role of SuSanA as an intermediary in these.

4.1 Evolution of urban sanitation approaches

Sanitation in low-income countries has been a topic of international development cooperation since approximately the 1970s. While most work in international development cooperation was focused on rural areas, some early work on urban sanitation was initiated by John Kalbermatten and his colleagues at the World Bank, who initiated in 1978 the United Nations Development Programme (UNDP)-World Bank Low-Cost Water and Supply and Sanitation Project (TAG) that became in 1987 the UNDP-World Bank Water and Sanitation Programme (WSP) in 1978 (Fig. 2). The project started to look into different, at that time still very controversial, technologies that took non-sewered sanitation as a starting point. Many called this direction 'unethical', because it contrasted with the grid-based sewerage paradigm that were considered as the international stand ard, safeguarding public health (especially among public health sector actors and engineers). Even though the WSP was a programme unit hosted within the World Bank, the Bank did, at that time, not finance the controversial work; the WSP was mainly financed by bilateral organisations via the UNDP.

The development of both sewerage systems and non-sewered sanitation options continued over the past decades. This led to two main approaches in sanitation provisioning in international development cooperation: (1) *Grid* approaches, based on centralised and decentralised waterborne sewerage systems. These originate from Europe in the nineteenth century, where they were invented to deal with the outbreak of waterborne diseases (Geels 2006). Ever since, sewerage has been considered the stand ard and most viable approach for sanitation in urban areas worldwide among most urban planners, utility managers, and donors (Fuenfschilling and Binz 2018). (2) Traditional *non-grid* approaches focussed on on-site toilet facilities without regular emptying and adequate treatment of the accumulated waste. These two approaches have dominated international development cooperation for decades. In projects in urban areas, the grid approach has been dominant and preferred by most governments, influential donors, and development agencies, because it was associated with modernity and seen as the ultimate solution for the urban sanitation problem. Traditional non-grid approaches were mainly used in projects in rural areas, but on-site projects, such as installing pit latrines, have also been implemented in cities, especially during the Millennium Development Goals (MDGs) period (2000–15), when latrines were installed in large numbers to reduce open defecation to meet the sanitation target. Until the 1990s innovations in both approaches were mostly incremental, for example in non-grid 'Ventilated Improved Pit latrines' and double-pit pour flush toilets were introduced, in the 1980s (Fig. 2). At the same time in grid approaches, incremental innovations to lower the costs of grid systems were introduced: condominial and simplified sewerage, and related decentralised wastewater treatment plants (Fig. 2).

The worldwide acceleration of urbanisation in the last two decades led to increasing attention for the shortcomings of both approaches to establish city-wide inclusive sanitation. To tackle these shortcomings new approaches, ideas, and technologies have been developed since the 1990s, to complement existing options.

One of the early alternatives proposed was ecological sanitation or *ecosan*.[3] Based on ecosystem thinking, this approach focused on 'closing the loop' and reuse of nutrients from human urine and faeces for agriculture. The approach was mainly promoted by a group of actors in western and northern Europe, such as development agencies (e.g. German and Swedish development organisations GIZ and SEI), during the 1990s (Fig. 2). These agencies considered ecosan as a sustainable solution for the global sanitation problem and invested in several ecosan projects around the world between the 1990s and the early 2000s. The promoted advantages were preventing (water) pollution, enhanced hygiene as a result of source separation and dehydration of faeces, safe use of products of human excreta for energy, nutrients and soil conditioner, and little material and energy use, compared to the existing approaches. The first International Ecosan Conference was organised in China in 2001. At the same time, however, the ecosan approach was contested by several research institutes, development agencies, and banks. It was criticised for its potential public health risks, lack of demand and acceptance among users, and cultural inappropriateness in certain contexts (e.g. the Arab and African countries). Opponents of ecosan feared that the ecological dimension of sanitation would overtake the priority of improving public health as the main goal of sanitation systems. It caused a lot of tension in the sector and proponents were even referred to as 'ecosan warriors' and 'freaks' (Black and Fawcett 2008: 123). Despite some successful pilot projects in different countries, the acceptance and uptake of ecosan was limited, even after decades of donor support. Towards the end of the 2000s, a majority

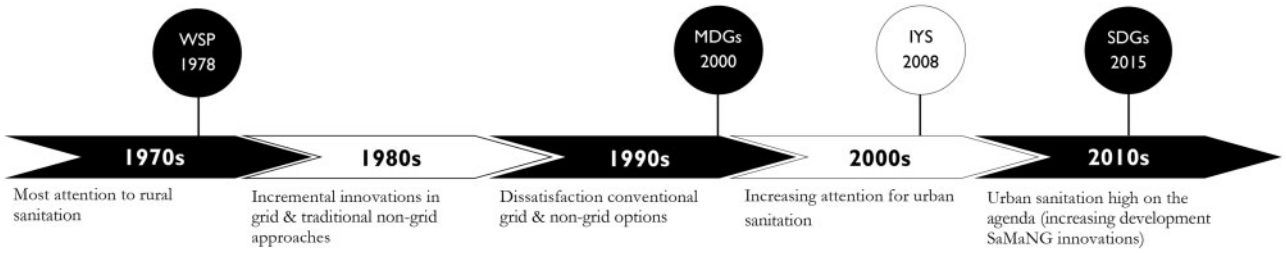

Figure 2. Representation of several of the main phases in the history of international development cooperation focused on urban sanitation (by the authors).

of the actors in international development cooperation eventually agreed that ecosan was not an encompassing one-size-fits-all solution for the shortcomings of the other approaches, and only appropriate in specific cases. Ecosan technology has never become an established alternative approach for urban sanitation. The term has been less-and -less used, and the last International Ecosan Conference was held in 2007.

The ecosan focus on Urine-Diversion Dry Toilets was a too narrow solution for the complex shortcomings of grid and non-grid approach. However, one could argue that the attention for resource recovery in the ecosan concept was the start of various other innovation developments focused on hand ling the waste from non-grid sanitation facilities in cities, from the early 2000s onwards (Fig. 2). These innovations were not characterised by a particular technology, but rather utilised a large variety of different approaches to establish sanitation systems. Many innovations that have been developed since the 2000s were non-grid focusing on safe capture, transport, treatment, and disposal or use of waste. They became known as *SaMaNG* approaches. This emerging technological field is envisioned to replace traditional non-grid facilities, and complements grid approaches, which remain very important in terms of investments and widespread implementation in cities worldwide. Slowly, leading international organisations start to agree a combination of SaMaNG and grid systems is needed to reach city-wide inclusive sanitation in low-income countries.

In the 2000s, the new emerging technological field was still populated by various actors that were separately testing many different types of SaMaNG approaches. Its further development was hampered by a lack of coordination, capabilities, and absence of a supportive institutional environment. Further development of the field required solving these system failures, in which intermediaries could play an important role.

4.2 SuSanA and safely managed non-grid sanitation innovation development

The developments of this emerging SaMaNG field during the last decade can be conceptualised as an emerging innovation system, because new types of institutional structures have been created, and actors started to engage collectively to build a favourable environment for new types of approaches (Musiolik et al. 2012; Planko et al. 2016). One of the prime movers in solving the coordination deficits in the sector and engaging in the development of SaMaNG has been the SuSanA network. We will now turn to its role as an intermediary in the activities since 2007.

As presented, since the early 2000s various development actors promoted different SaMaNG approaches, and there were several controversies about the newly developed concepts and approaches. As sanitation was put on the (political) agenda in the International Year of Sanitation (IYS) in 2008 (Fig. 2), there was an urgent need for consensus-building and coordination among sanitation actors. Collective advocacy for the general importance of sustainable sanitation during this year was required. Furthermore, the IYS provided a chance to improve legitimation, mobilise resources, increase knowledge, and create markets for SaMaNG innovations. Therefore, in preparation of the IYS, a small number of German, Swedish, and Swiss research institutes, private companies, and development agencies established SuSanA. SuSanA supported the development of sustainable sanitation approaches[4] through the coordination of activities, compiling information, and development of visions.

4.2.1 Phase 1 (2007–09)—alignment and articulation

In its establishing year 2007, thirty-eight organisations joined SuSanA as partners.[5] A core group of individual experts representing different organisations (mainly based in the Global North) was established to govern the network *(alignment)*.[6] Contributions to the network were voluntary. In this phase, advocacy for the general recognition of the importance of sanitation was very necessary, because water provision dominated the policy agendas of most large development agencies and donors. SuSanA established a network and raised awareness of the sanitation problem, and about particular sustainability problems of the conventional grid and non-grid approaches *(learning)*. The early partners of SuSanA tried to reach consensus among each other on basic principles of sustainable sanitation, and created a joint vision document to broadly articulate the innovation needs, in 2008 (Fig. 3). This document pleaded for action in the sanitation sector and outlined five aspects that should be considered to design sustainable sanitation systems, related to: health and hygiene; environment and natural resources; technology and operation; financial and economic issues; socio-cultural and institutional factors. At that time, the vision was innovative because it was not just pleading for access to sanitation, but explicitly opened-up the discussion that urban sanitation is a very complex problem for which no simple solutions based on a single approach exist. This document was based on joint knowledge of individual actors and gave a broad direction for *guidance of search* in the sector at *transnational level* (Fig. 3). SuSanA's vision document was translated into eleven languages. New organisations that became partner of SuSanA agreed with the network's vision on sustainable sanitation. Not all important actors in the sector joined SuSanA in these early years, however, because several of SuSanA's founders were closely associated with the ecosan community. Their association with ecosan made that SuSanA, initially, met with a lot of scepticism by these actors. The ecosan-image hindered SuSanA in its early years, but this perception slowly disappeared and more and more organisations became partners of the network (Fig. 4).

SuSanA established various thematic working groups that deal with specific aspects of sustainable sanitation, such as capacity

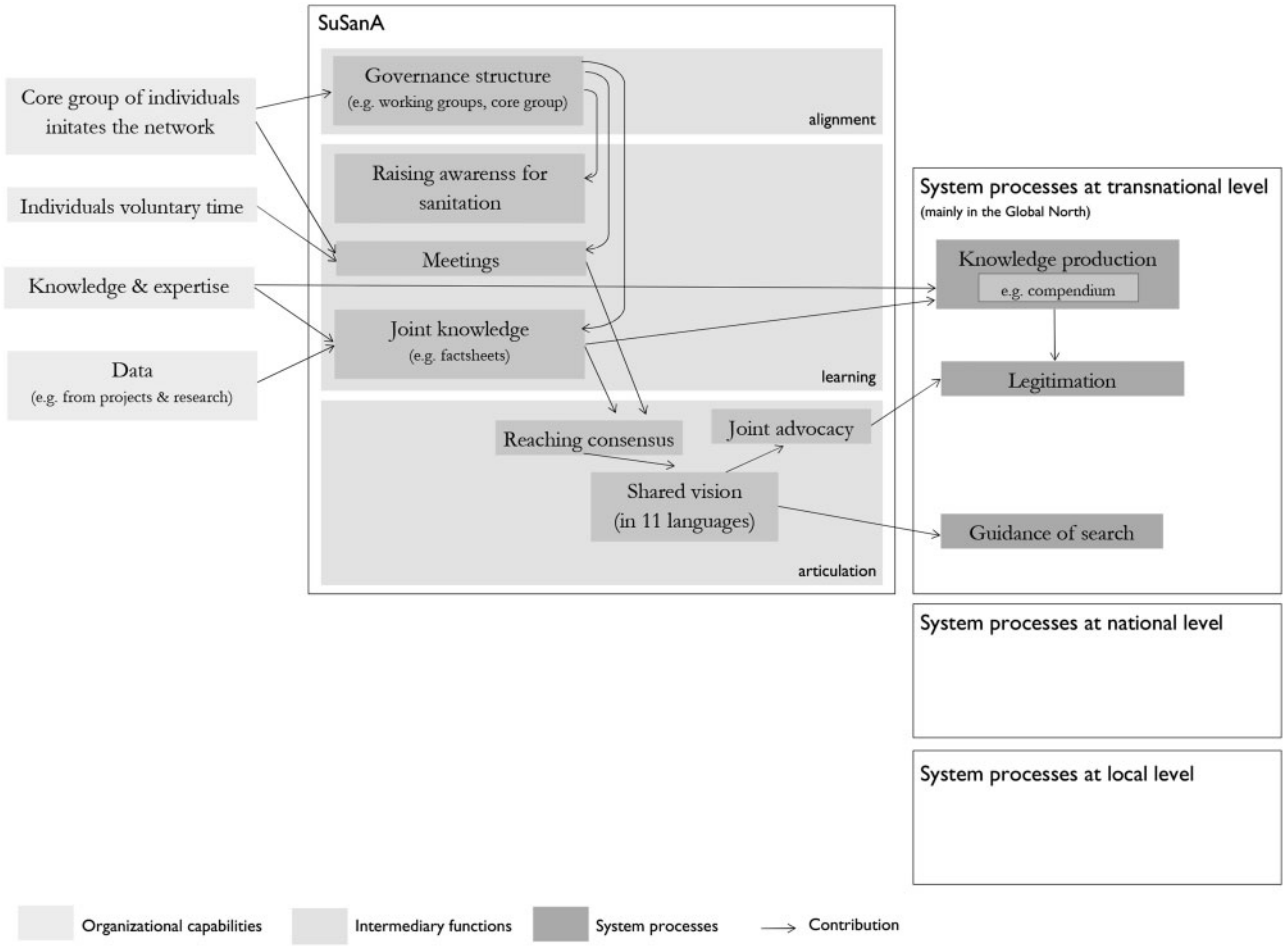

Figure 3. SuSanA's contribution to innovation system building for SaMaNG in phase 1 (2007–9).

development, sanitation systems and technology options, cities, and renewable energies and climate change. These working groups created factsheets, which outlined a specific aspect relevant for sustainable sanitation and how to address this aspect. Much of the attention went to SaMaNG solutions, compared to grid solutions. The creation of these factsheets brought together individual organisations that contributed knowledge, expertise, and data. The discussions in the working groups led to consensus building among SuSanA partners about the different aspects of sustainable sanitation, and thereby supported knowledge production for the broader innovation system (Fig. 3).

A concept that gained broad interest in this period within SuSanA as well as the wider sector, was 'sanitation system thinking' using the concept of a 'sanitation chain' that include: capture, transport, treatment, and use or disposal of waste. This idea was strengthened by an influential new knowledge source, the Compendium of Sanitation Technologies, published by Eawag-Sand ec in collaboration with SuSanA partners in 2008 (see Tilley et al. 2008; Fig. 3). This publication elaborated all different technologies that can be used to design a sanitation system covering the steps of the sanitation chain. This was a fundamentally different way of thinking than in the traditional non-grid approach, which only focused on the first step of the sanitation chain: capturing waste. Moreover, the Compendium incorporated for the first time both grid and non-grid approaches in one framework, and showed how both can safely manage waste, which contributed to creation of legitimacy for SaMaNG innovations. The sanitation chain concept also formed the basis for the principles of 'Faecal Sludge Management' (FSM). Faecal sludge is the waste that comes from on-site sanitation systems, such as pit latrines, septic tanks, dry toilets, or non-sewered public ablution blocks. FSM includes the storage, collection, transport, treatment, safe end use or disposal of faecal sludge. In this period, innovation development in the sanitation sector was also strengthened by a large number of evidence-based research projects. For example, the World Health Organization published work on sanitation investments, showing that sanitation improvements were cost-effective in low-income countries (see Hutton et al. 2007).

In this phase (2007–9) SuSanA focused mainly on network formation and started to articulate the needs of the emerging SaMaNG field, for example in the factsheets of the working groups. This contributed to *legitimacy* creation and the start of developing *guidance of search* (Fig. 3). In this phase, the achievements of SuSanA and the other actors, represented important building blocks for the development of the SaMaNG innovation system at *transnational level*, mainly among actors in the Global North. System processes at national and local level lacked behind in this phase. SuSanA did not actively support multi-scalar relationships that would span across the Global North and South and could lead to structural couplings between different subsystems.

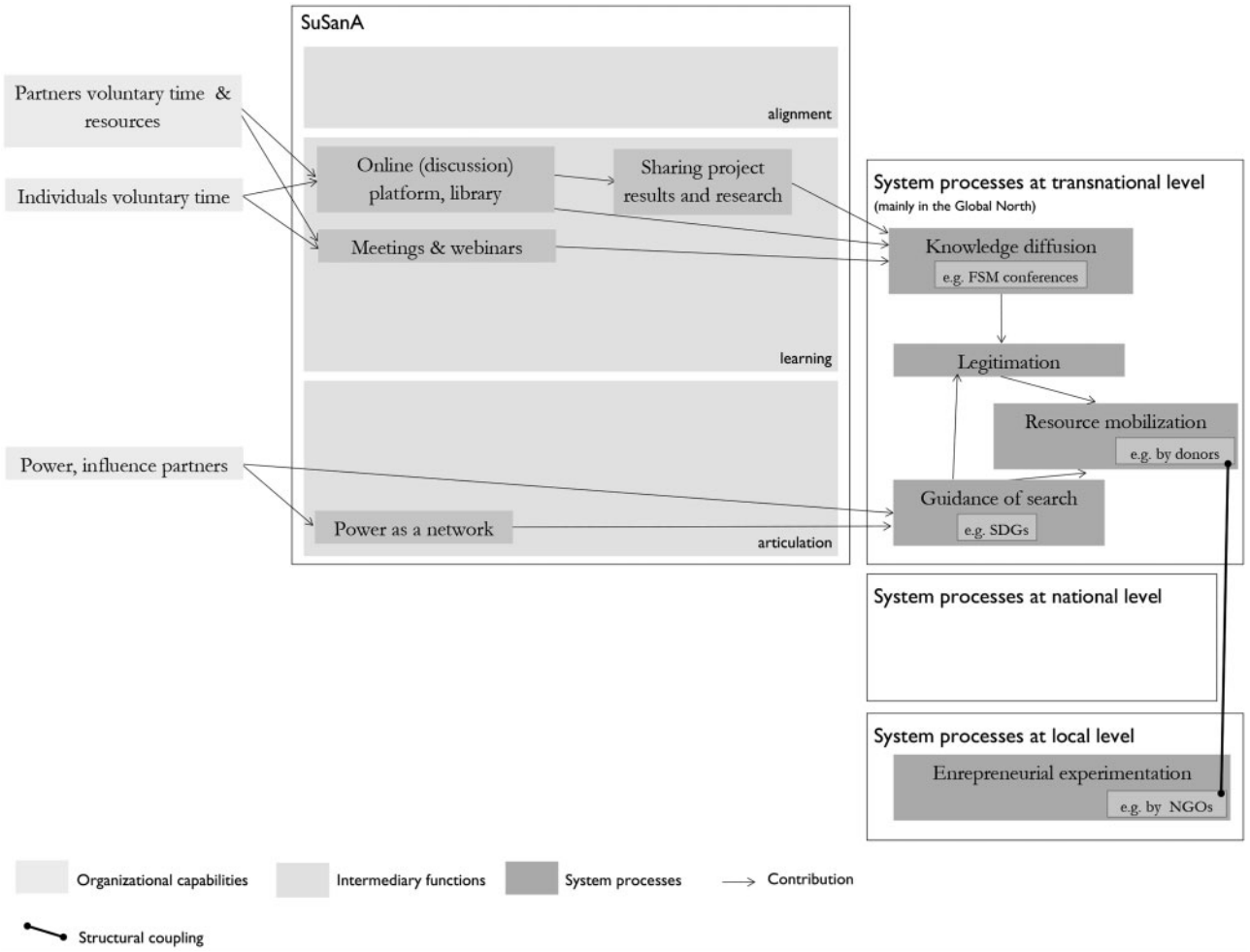

Figure 4. SuSanA's contribution to innovation system building for safely managed non-grid sanitation in phase 2 (2010–16).

4.2.2 Phase 2 (2010–16)—supporting learning processes

In this period, the SaMaNG field became more and more established. First, the concept of sanitation chains was increasingly applied by (influential) actors in the sector. This led to *knowledge diffusion* and *legitimation*. The involvement of influential actors led to increased resource mobilisation for SaMaNG innovation at the *transnational level* (Fig. 4). For example, the Bill and Melinda Gates Foundation (BMGF) entered the sector as a very important donor organisation around 2011, and strongly supported SaMaNG approach. Secondly, from 2012 onwards, the Joint Monitoring Programme of the United Nations (led by WHO and UNICEF) started to consult key sanitation experts in the process of developing the successor of the MDGs. In this process, many research organisations and development agencies were consulted, among them many partners of SuSanA and by this strongly conditioned *guidance of search* at the *transnational level* (Fig. 4). Ultimately this led to more ambitious sanitation targets in a new set of goals, the Sustainable Development Goals (SDGs), adopted by the UN in 2015. In terms of sanitation, the discourse of the MDGs changed radically. The SDGs did not just aim for increased 'access to sanitation', but instead called for 'safely managed sanitation services'. This strengthened the *legitimation* and *guidance of search* of innovative activities in the emerging innovation system at *transnational level* (Fig. 4). With the introduction of the SDGs, discussions about SaMaNG innovations became mainstream. More and more actors, including donors, got involved in innovation development, which was also reflected in the membership of SuSanA that rose in this phase, and became more diverse in terms of types of actors and their location (Fig. 5).

Furthermore, some other specific organisational structures were set-up, which improved system building. An example was the FSM Committee, established in 2011, in which leading global sector organisations coordinated their ideas on FSM and initiated the first International FSM conferences. These conferences led to knowledge diffusion and the number of participants attending these conferences grew rapidly. The first conference in 2012 in South Africa assembled less than 100 participants, while the most recent conference in 2019 in Cape Town attracted over a 1,000 participants. Knowledge production and diffusion was also strengthened in an increasing number of publications and books, education programmes, toolboxes, and online courses. Resource mobilisation also steadily increased—especially the BMGF had a very influential role in supporting FSM research and projects, which led to the development of linkages between the system processes *(resource mobilisation)* at the *transitional level* and *(entrepreneurial) experimentation* at the *local level*. Furthermore, in the last decade, the World Bank began to show interest in SaMaNG innovation, among other things, FSM. Initially, the development banks found it challenging to fund small (innovative) FSM projects as these include multiple (private) stakeholders,

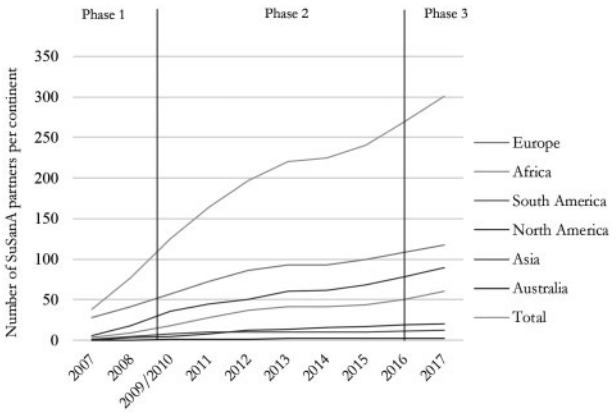

Figure 5. Growth in SuSanA membership counts per continent 2007–17 (made by the authors based on data from the SuSanA secretariat).

while they conventionally funded large (sewer-based) projects through one (public) institution. New funding approaches needed to be developed, in which FSM was included as components of large sewerage projects. All-in-all, *(entrepreneurial) experimentation* at the *local level* took off in this phase.

As major actors started to show interest in SaMaNG innovation, the role of SuSanA in *demand articulation* and *network formation* declined. Many of the original working groups became relatively inactive. In this phase, however, SuSanA was still an important initiator of many activities related to learning and retained its role as a knowledge sharing and coordination platform. It facilitated discussions, shared knowledge, and compiled information. The network established an online library and project database dedicated to sanitation. This became one of the most extensive online information sources solely dedicated to sanitation, which contributed *knowledge diffusion at the transnational level*. The network also launched an online discussion forum in 2011, where individuals could ask questions and discuss issues related to sustainable sanitation. It was open to anyone and was used by a variety of sanitation practitioners, which gave a boost to the individual membership counts. In addition to managing the online discussion and knowledge platforms, SuSanA organised meetings and webinars, which contributed to *knowledge diffusion* in the emerging *transnational* innovation (sub)-system (Fig. 3). The German Ministry of Economic Cooperation and Development and BMGF supported SuSanA[7] for its role as important knowledge sharing platform in the sector, during this phase. Moreover, all BMGF grantees were expected to share the outcomes of their projects and research on the SuSanA platforms, which also contributed to the rise of members of SuSanA. Various SaMaNG technologies and approaches were discussed on the SuSanA forum. For example, faecal sludge transport and treatment, faecal sludge characteristics, public awareness for non-grid sanitation, business models for non-grid systems, and city-wide inclusive sanitation planning. SuSanA also played a key role in sharing presentations, reports, and documents from relevant conferences.

In this period SuSanA's main role was related to *learning*: it enhanced learning processes across multiple actors, and facilitated discussions and cooperation for innovation. This mainly contributed to broader innovation system building activities at *transnational level* in terms of *knowledge diffusion* (Fig. 4). Similarly as in the first phase, SuSanA mainly supported system building at the *transitional level* among actors in the Global North, which strengthened the new SaMaNG field in international development cooperation. The development of links between the broader system building activities at the transnational level to system processes at the local level were mainly supported by international development banks and donors such as the BMGF, as well as national development organisations such as GIZ, which were active in the system building processes at transnational level, as well as in supporting *entrepreneurial experimentation* by NGOs and other organisations, at the *local level* (Fig. 4). In this phase, SuSanA did not actively support system processes at national or local level, and did not focus on the creation of multi-scalar relationships between the transnational level and processes at other levels.

4.2.3 Phase 3 (from 2017 onwards) — directionality and global reach

In the third and latest phase, the growing SaMaNG innovation system was challenged to contribute to developing specific institutions, selecting dominant designs, and forming (local) markets.

However, despite the consensus reached on the sustainability criteria, little further agreement emerged in terms of which technologies and approaches are most promising for maturing the SaMaNG innovation system (*guidance of search*). Actors were still developing a wide variety of options. Furthermore, despite the system building activities in the previous phases, implementation beyond experimentation was still rare, which hampered *market formation* for SaMaNG innovations in cities (*legitimation at the local level*). Only in a few countries successful experiments with city-wide implementation were conducted, which could serve as examples for other cities. Many uncertainties about which technological options or approaches to select and develop still prevailed. The lack of directionality was also reflected in SuSanA. The network had so far formulated general sustainability criteria that should be considered, but within the network all different kinds of SaMaNG technologies were nurtured. The emphasis had been on technological variety, not on evidence-based selection. SuSanA was hesitant to move away from this strategy, because of the large variety needed to cater for different geographical contexts. Furthermore, NGOs and private sector actors have constituted a majority of SuSanA's partners since 2012 (Fig. 6). Actors working on small-scale implementation and experiments were therefore overrepresented in the network, whereas partners that would be able to cater for city-wide implementation of SaMaNG innovations, such as Ministries, local governments and city planners were relatively underrepresented (Fig. 6). This hampered SuSanA's ability to support the articulation of demand -side needs that could lead to market formation of SaMaNG innovations on a city-wide scale.

Another problem that hampered the SaMaNG innovation system, was the limited geographical reach of its developments so far. These had mainly led to system processes at the transnational level in the Global North (Figs 3 and 4). Experiments and increased legitimation for SaMaNG innovation in cities in low-income countries were limited to a few countries in the Global South, compared to the increased legitimation and *knowledge production and diffusion* at transnational level among actors in the Global North. This was also reflected in SuSanA. The activities of the network so far had a tendency to take place and be driven by actors in the Global North, especially by European actors, while North American and Australian actors were less connected to the network. Although the share of Asia- and Africa- based partners grew over the last decade, European research institutes and development agencies still took the lead and were most active (Fig. 7). Among other things because

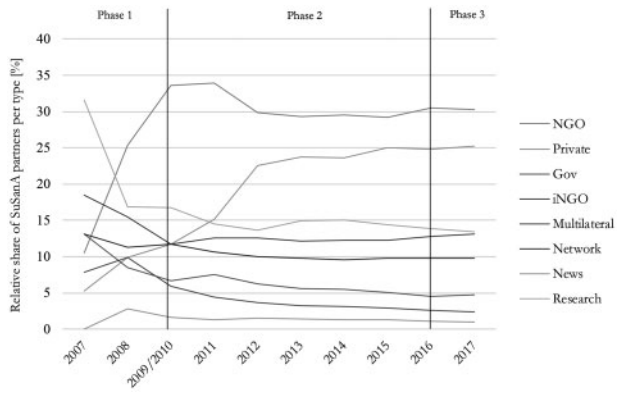

Figure 6. Relative share of SuSanA partners per type 2007–17 (made by the authors based on data from the SuSanA secretariat).

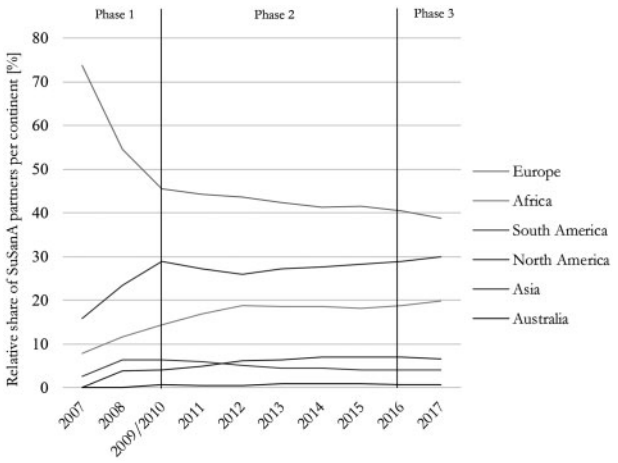

Figure 7. Relative share of SuSanA partners based on different continents 2007–17 (made by the authors based on data from the SuSanA secretariat).

these actors had more (financial) resources that enabled them to contribute voluntarily to the network. The Global North bias of SuSanA was acknowledged by its core group, and in order to improve the link to specific regions in the Global South, SuSanA recently set-up local 'chapters' in India, West Asia and North Africa, and Latin America (Fig. 8). The chapters are supposed to help these regions with their local needs in terms of coordination, demand articulation, and context-specific *knowledge development*, and to make SuSanA's knowledge and services more accessible on the ground (Fig. 8).

In this last phase, SuSanA's contribution to system development changed, as a start was made to contribute to system processes at national and local levels. The regional chapters might contribute to connect the developments of *guidance of search* or *legitimation* at the *transnational level*, to actors and networks that support processes of *(entrepreneurial) experimentation* at *local levels* (Fig. 8).

All in all, SaMaNG innovations became more prominent on the global agenda, but progress on the ground had not been made at the required scale and speed.

5. Discussion and conclusion

In this article, we reconstructed how a transnational technology field emerged and got consolidated around SaMaNG, which challenged the existing, dominant approaches to provide urban sanitation in the Global South. We analysed core formation processes from the perspective of global technological innovation systems and emphasised the role of a specific intermediary aimed at coordinating the field at a global scale. We will now discuss the main findings, followed by the theoretical contributions, and an elaboration of future research questions.

SuSanA contributed to mission-oriented system-building activities that strengthened the development of a new SaMaNG field to overcome the shortcomings of the previously dominating sanitation approaches. In the first phase (2007–9) SuSanA facilitated activities that contributed to *articulation* and *alignment*. These intermediary functions contributed to the development of system processes, most notably *legitimation* and general *guidance of search*. At an early stage, SuSanA shaped a general shared vision that SaMaNG is an important approach for providing sustainable sanitation services. In the second phase (2010–16) SuSanA's role changed and it mainly contributed to *learning*: knowledge gathering and dissemination among multiple actors and facilitating discussions. These activities contributed to *knowledge diffusion*. The alignment and learning activities also indirectly contributed to *resource mobilisation* in the field. Donors started to create multi-scalar relationships through their involvement in both *resource mobilisation* at the *transnational* level, as well as *(entrepreneurial) experimentation* at the local level. In the first two phases, SuSanA did not contribute much to subsystem development at other levels, or structural couplings. In the third phase (2017 onwards), the SaMaNG innovation system has been growing. However, necessary steps towards maturation, such as the formation of specific institutions, the selection of dominant designs, and formation of markets, are still not fully developed. SuSanA focused primarily on coordinating actors located in the Global North: research institutes, donors, private sector actors, and development agencies in order to channel activities by these actors. Only in the latest phase, SuSanA started to focus on connecting interfaces between the transnational subsystem and potential other subsystems, with the establishment of SuSanA's regional chapters. All in all, SuSanA has so far mainly supported system processes at the transnational level that mostly assembled actors located in the Global North. Cross-boundary alignment and articulation have not taken place, yet. The structural couplings between these transnational developments and local implementation contexts were insufficient or even absent. This may seriously hamper the emergence of a well-established global innovation system.

The analysis shows that even if the past ten years have been very successful in building up core innovation system structures, the current challenges signal a new phase of system building and therefore require new sets of intermediary functions. The analysed challenges lead to the following two aspects that intermediaries in transnational innovation systems should address. First, stronger forms of *guidance of search* are required to strengthen resource mobilisation and market formation. This asks for a better understand ing of local conditions and demand -side development, to be able to select promising potential dominant designs. However, stronger forms of guidance of search can come at the expense of a broad variety of alternative designs that is required to accommodate for the needs in different geographical contexts. For SuSanA, strict technology neutrality has been programmatic for its strategy so far. A gradual shift towards supporting (selection processes of) dominant designs, might decrease its ability to unite actors, and jeopardise its legitimacy as an intermediary that it has build-up in the field. In general there is

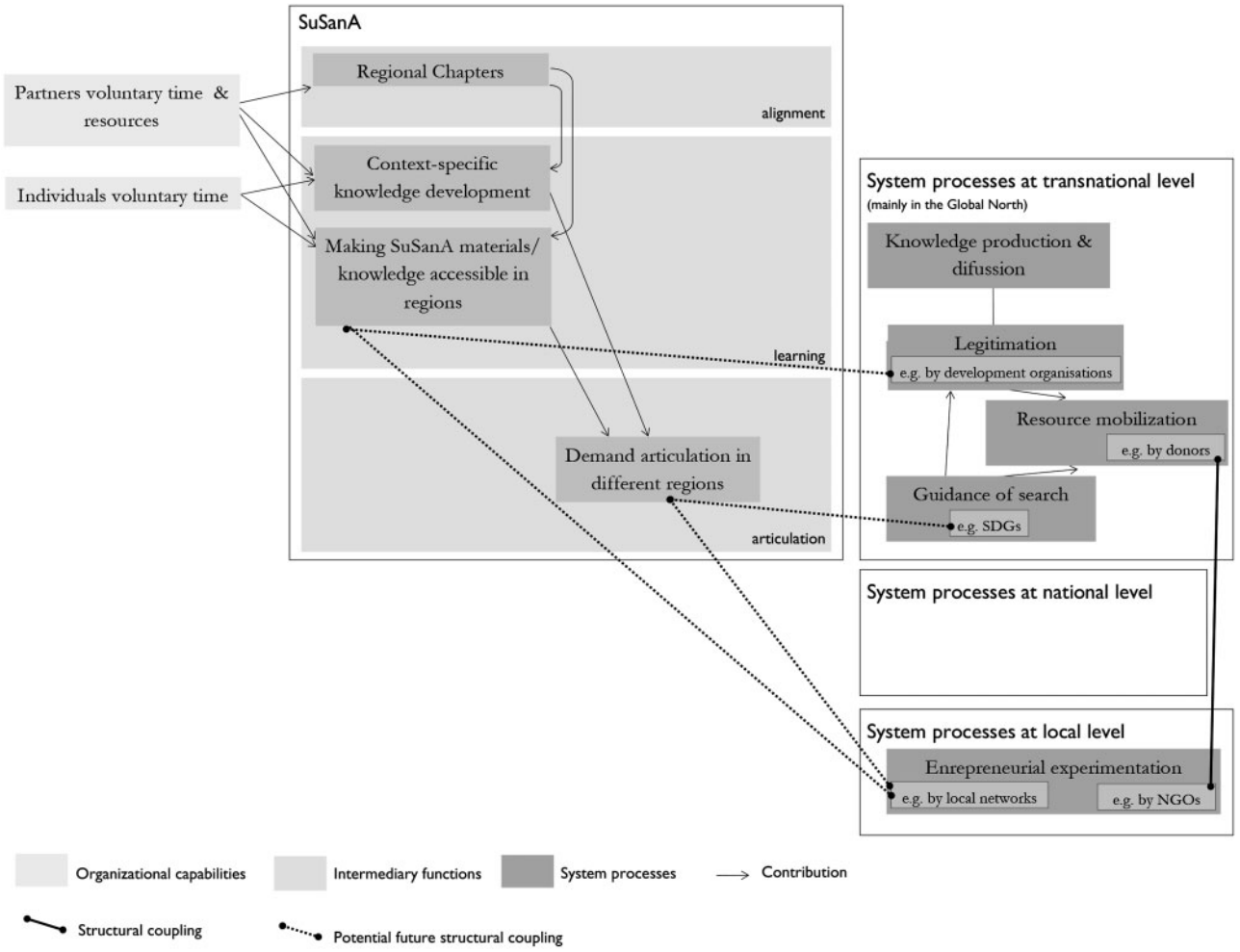

Figure 8. SuSanA's (potential future) contribution to innovation system building for safely managed non-grid sanitation in phase 3 (2017 onwards).

nothing wrong with systemic intermediaries becoming more directional (Kivimaa et al. 2018), but this requires different sets of skills and resources, and for other actors to agree with the intermediary's new positioning (van Lente et al. 2003).

Secondly, transnational intermediaries have to have a broad geographical scope of innovation system developments to strengthen local institutional contexts. Structural couplings thus need to be formed, as they help to effectively combine knowledge, investments, markets, and legitimacy across different geographical scales. Transnational intermediaries should support and connect implementation-related system building efforts in different parts of the world. They would, for example, have to warrant that the systemic resources that are developed in different places, for example regarding specific knowledge stocks, forms of legitimation, resource mobilisations etc., are made available to actors in other regions. Establishing these structural couplings is, however, more complicated than solving conventional coordination deficits or 'simple brokerage', and it would presumably require contributions to overcoming institutional and cultural gaps between different institutional environments as emphasised by Stadtler and Probst (2012), Ma et al. (2014), Pfotenhauer et al. (2016), and Klerkx and Guimón (2017). In terms of the global innovation system framework, what is at stake is the formation of a multi-scalar network of connected subsystems.

For SuSanA, this latter challenge would require a substantial extension of the current mand ate, resources, and actor coverage. Some developments in this direction are observed by the recent foundation of Indian, Latin American, West Asian, and North African regional chapters of SuSanA, which aim at coordinating local actors and intermediaries. However, for an intermediary like SuSanA, it might be difficult to expand to a global network of thousand s of partners running local initiatives all across the world. Rather, innovation system processes in different countries and regions should be supported and connected. This could be achieved by linking local intermediaries, actors, and networks (e.g. local city advocacy groups, national sectoral platforms, utilities, municipalities) to the transnational system processes. Our analysis thus shows the need of an 'ecology of intermediaries' in transnational innovation system processes, with different capabilities, resources and operational modes (Kivimaa et al. 2018). Moreover, it seems necessary that the composition of this ecology of intermediaries changes in the different phases of innovation system building towards maturation of a technological field (Kivimaa et al. 2019).

More generally, our findings have implications for science and innovation policy as they reveal that it is demand ing to fulfil an intermediary role in a mission-oriented innovation system that addresses global societal challenges, because of the need to consider system processes at different scales, in each phase of innovation

system building. Intermediaries might have to focus on specific system functions and adopt a rather neutral role in the formative phase in order to build networks and generate general legitimacy for a field. In the growth phase, they rather need to support stronger forms of guidance of search and have to enable subsystem formation at different geographical scales as well as supporting sufficient structural couplings between them. By this, our study contributes with explicit empirical insights on how innovation intermediation changes over time, a topic that has only been picked up recently by for example Kant and Kanda (2019). As such, our study advances the understand ing of the role of intermediaries in transitions (Kivimaa et al. 2018, 2019). The analytical framework (Fig. 1) that we introduced in this article extends the focus of the literature on intermediaries to the specific challenges that intermediaries have to confront in global innovation system contexts. The insights that are gained using our analytical framework contribute to identifying the challenges of intermediaries with broad objectives, such as contributing to the SDGs, and to solving a grand societal challenge (e.g. as compared to an intermediary supporting one specific sustainable product).

The explorative character of this research gives several pointers for further research. We showed that coordination between actors and scales is tightly linked to cognitive choices that need to be made within the innovation system in terms of technologies (the choice for a specific technology or remaining neutral), as well as legitimising the mission of the innovation system vis-à-vis competing missions and visions as to how to address societal challenges. As the solution to the grand challenges like global sanitation cannot be tackled by any national innovation system alone, state-based development agencies, donors, the private sector, research institutes, and international NGOs have to team up for finding solutions that will become globally accepted while respecting the specific local context conditions. Such 'ecology of intermediaries' will lead to inequalities and conflicts, which should be identified in more detail in future research. The interactions between different intermediaries, in particular with regard to whether they complement or compete with each other in an 'ecology' would be important to analyse (see e.g. Klerkx and Aarts 2013; Martiskainen and Kivimaa 2018).

As our analysis has focused on one specific intermediary, we encourage research on a broader range of organisational structures, funding models, mand ates, and geographical reach of intermediaries in mission-oriented innovation systems. Furthermore, in the present article, we were not able to reflect on the interaction among the mostly European country-driven SuSanA network and alternative endeavours for instance by American agencies. Such a broader view would be necessary to reconstruct the fully global dimension of this emerging global innovation system. Also, the (potential) role of south-south intermediaries to create structural couplings between subsystems should be further investigated. Finally, the analysis of global innovation systems in the context of missions seems a promising way forward to better understand and eventually address grand societal challenges.

Supplementary data

Supplementary data is available at *Science and Public Policy Journal* online.

Acknowledgements

The authors would like to thank all the interviewees for their participation in this research. In addition, we would like to thank Christoph Lüthi, Dorothee Spuhler, and Roland Schertenleib for their very helpful extensive comments on earlier versions of this article. The article also benefited from discussions with Abishek Sankara Narayan, as well as information received from Franziska Volk and Shobana Srinivasan of the SuSanA Secretariat.

Funding

This work was supported by the Swiss National Science Foundation [grant number 10001 A_159300].

Conflict of interest statement. None declared.

Notes

1. International development cooperation is increasingly diverse and includes a range of diverse activities and actors. Its goals can be summarized as: (1) guaranteeing universal basic stand ards of social protection; (2) promote convergence among countries' stand ards of living; (3) support efforts of low-income countries to participate in provision of international public goods. It is explicitly meant to support national or international development priorities; not driven by profit; discriminates in favor of low-income countries and is based on cooperative relationships that seek to enhance low-income country ownership. International development cooperation can have the form of financial transfer, capacity support or policy change (Alonso and Glennie, 2015).
2. GIZ—Gesellschaft für Intern Zusammenarbeit (German Corporation for International Cooperation)
3. The principles underlying ecosan were not new: sanitation systems based on ecological principles have been used for hundreds of years in different cultures. However, at the end of the 1990/2000s, there was a revival of interest in ecosan (Langergraber and Muellegger 2005) as an option for low-income countries in the international development community. Exemplary is that the most widely-cited source of ecological sanitation (Esrey et al. 1998) was written by the Swedish International Cooperation Agency (Brands 2014).
4. SuSanA supported any sustainable sanitation approach. In this article, however, we focus specifically on SuSanA's role in supporting safely managed non-grid innovations for cities.
5. Research organizations dominated the partner base of the network in this first phase (Fig. 5), and most partner organizations were based in Europe (Fig. 7).
6. From this point onwards we will highlight the terms used in our analytical framework for better conceptual understand ing of the case.
7. BMGF has financed the SuSanA secretariat based at GIZ since the start. The secretariat maintains the platform and organizes SuSanA meetings.

References

Alonso, J. A., and Glennie, J. (2015). *What is Development Cooperation? 2016 Development Cooperation Forum Policy Briefs* <http://www.un.org/en/ecosoc/newfunct/pdf15/2016_dcf_policy_brief_no.1.pdf> accessed 14 Feb 2019.

Andersson, K., Dickin, S., and Rosemarin, A. (2016) 'Towards "Sustainable" Sanitation: Challenges and Opportunities in Urban Areas', *Sustainability*, 8/12: 1–14.

Asheim, B. T., and Gertler, M. S. (2005). *The Geography of Innovation: Regional Innovation Systems*. In: J. M., Fagerberg and R. D., Nelson (eds),

The Oxford Hand book of Innovation, pp. 291–317. Oxford: Oxford University Press.

Bergek, A., Hekkert, M., Jacobsson, S. et al. (2015) 'Technological Innovation Systems in Contexts: Conceptualizing Structures and Interaction Dynamics', *Environmental Innovation and Societal Transitions*, 16: 51–64.

———, Jacobsson, S., Carlsson, B. et al. (2008) 'Analyzing the Functional Dynamics of Technological Innovation Systems: A Scheme of Analysis', *Research Policy*, 37: 407–29.

Bessant, J., and Rush, H. (1995) 'Building Bridges for Innovation: The Role of Consultants in Technology Transfer', *Research Policy*, 24/1: 97–114.

Binz, C., and Truffer, B. (2017) 'Global Innovation Systems - A Conceptual Framework for Innovation Dynamics in Transnational Contexts', *Research Policy*, 46: 1284–98.

Black, M., and Fawcett, B. (2008). *The Last Taboo. Opening the Door on the Global Sanitation Crisis*. London: Earthscan.

Blum, N. U., Bening, C. R., and Schmidt, T. S. (2015) 'An Analysis of Remote Electric Mini-Grids in Laos Using the Technological Innovation Systems Approach', *Technological Forecasting and Social Change*, 95: 218–33.

Boon, W. P. C., and Edler, J. (2018) 'Demand , Challenges, and Innovation. Making Sense of New Trends in Innovation Policy', *Science and Public Policy*, 45/4: 435–47.

———, Moors, E. H. M., Kuhlmann, S. et al. (2011) 'Demand Articulation in Emerging Technologies: Intermediary User Organisations as Co-Producers?', *Research Policy*, 40/2: 242–52.

Brands, E. (2014) 'Prospects and Challenges for Sustainable Sanitation in Developed Nations: A Critical Review', *Environmental Reviews*, 22/4: 346–63.

Bush, R. E., Bale, C. S. E., Powell, M. et al. (2017) 'The Role of Intermediaries in Low Carbon Transitions – Empowering Innovations to Unlock District Heating in the UK', *Journal of Cleaner Production*, 148: 137–47.

Carlsson, B., and Stankiewicz, R. (1991) 'On the Nature, Function and Composition of Technological Systems', *Journal of Evolutionary Economics*, 1: 93–118.

Coenen, L., Benneworth, P., and Truffer, B. (2012) 'Towards a Spatial Perspective on Sustainability Transitions', *Research Policy*, 41: 968–79.

Cooke, P., Gomez Uranga, M., and Etxebarria, G. (1997) 'Regional Innovation Systems: Institutional and Organisational Dimensions', *Research Policy*, 26/4: 475–91.

Cresswell, J. W. (2009). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*. California: SAGE Publications.

Esrey, S., Gough, J., Rapaport, D. et al. (1998). *Ecological Sanitation* <Swedish International Development Cooperation Agency. Sida S-105-25: http://www.ecosanres.org/pdf_files/Ecological_Sanitation.pdf> accessed 14 Feb 2019.

Foray, D., Mowery, D. C., and Nelson, R. R. (2012) 'Public R&D and Social Challenges: What Lessons from Mission R&D Programs?', *Research Policy*, 41/10: 1697–702.

Frenken, K. (2017) 'A Complexity-Theoretic Perspective on Innovation Policy', *Complexity, Innovation and Policy*, 3/1: 35–47.

Fuenfschilling, L., and Binz, C. (2018) 'Global Socio-Technical Regimes', *Research Policy*, 47/4: 735–49.

Geels, F. W. (2006) 'The Hygienic Transition from Cesspools to Sewer Systems (1840-1930): The Dynamics of Regime Transformation', *Research Policy*, 35/7: 1069–82.

Hekkert, M. P., Suurs, R. A. A., Negro, S. O. et al. (2007) 'Functions of Innovation Systems: A New Approach for Analysing Technological Change', *Technological Forecasting & Social Change*, 74: 413–32.

Howells, J. (2006) 'Intermediation and the Role of Intermediaries in Innovation', *Research Policy*, 35/5: 715–28.

Hutton, G., Haller, L., and Bartram, J. (2007) 'Global Cost-Benefit Analysis of Water Supply and Sanitation Interventions', *Journal of Water and Health*, 5/4: 481.

Intarakumnerd, P., and Chaoroenporn, P. (2013) 'The Roles of Intermediaries in Sectoral Innovation System in Developing Countries: Public Organizations Versus Private Organizations', *Asian Journal of Technology Innovation*, 21/1: 108–19.

Jewitt, S. (2011) 'Geographies of Shit: Spatial and Temporal Variations in Attitudes Towards Human Waste', *Progress in Human Geography*, 35/5: 608–26.

Kant, M., and Kanda, W. (2019) 'Innovation Intermediaries: What Does it Take to Survive Over Time?', *Journal of Cleaner Production*, 229: 911–30.

Kebede, K. Y., and Mitsufuji, T. (2017) 'Technological Innovation System Building for Diffusion of Renewable Energy Technology: A Case of Solar PV Systems in Ethiopia', *Technological Forecasting and Social Change*, 114: 242–53.

Kilelu, C. W., Klerkx, L., Leeuwis, C. et al. (2011) 'Beyond Knowledge Brokering: An Exploratory Study on Innovation Intermediaries in an Evolving Smallholder Agricultural System in Kenya', *Knowledge Management for Development Journal*, 7/1: 84–108.

Kivimaa, P. (2014) 'Government-Affiliated Intermediary Organisations as Actors in System-Level Transitions', *Research Policy*, 43/8: 1370–80.

———, Boon, W., Hyysalo, S. et al. (2018) 'Towards a Typology of Intermediaries in Sustainability Transitions: A Systematic Review and a Research Agenda', *Research Policy*, 48/4: 1062–75.

———, Hyysalo, S., Boon, W. P. C. et al. (2019) 'Passing the Baton: How Intermediaries Advance Sustainability Transitions in Different Phases', *Environmental Innovation and Societal Transitions*, 31: 110–25.

Klein Woolthuis, R., Lankhuizen, M., and Gilsing, V. (2005) 'A System Failure Framework for Innovation Policy Design', *Technovation*, 25: 609–19.

Klerkx, L., and Aarts, N. (2013) 'The Interaction of Multiple Champions in Orchestrating Innovation Networks: Conflicts and Complementarities', *Technovation*, 33/6: 193–210.

———, Álvarez, R., and Campusano, R. (2015) 'The Emergence and Functioning of Innovation Intermediaries in Maturing Innovation Systems: The Case of Chile', *Innovation and Development*, 5/1: 73–91.

———, and Guimón, J. (2017) 'Attracting Foreign R&D Through International Centres of Excellence: Early Experiences from Chile', *Science and Public Policy*, 44/6: 763–74.

———, and Leeuwis, C. (2009) 'Establishment and Embedding of Innovation Brokers at Different Innovation System Levels: Insights from the Dutch Agricultural Sector', *Technological Forecasting and Social Change*, 76/6: 849–60.

Koné, D. (2010) 'Making Urban Excreta and Wastewater Management Contribute to Cities' Economic Development: A Paradigm Shift', *Water Policy*, 12/4: 602–10.

Kriechbaum, M., Brent, A. C., and Posch, A. (2018) 'Interaction Patterns of Systemic Problems in Distributed Energy Technology Diffusion: A Case Study of Photovoltaics in the Western Cape Province of South Africa', *Technology Analysis & Strategic Management*, 1–15.

Kuhlmann, S., and Rip, A. (2018) 'Next-Generation Innovation Policy and Grand Challenges', *Science and Public Policy*, 45/4: 448–54.

Lamers, D., Schut, M., Klerkx, L. et al. (2017) 'Compositional Dynamics of Multilevel Innovation Platforms in Agricultural Research for Development', *Science and Public Policy*, 44/6: 739–52.

Langergraber, G., and Muellegger, E. (2005) 'Ecological Sanitation—A Way to Solve Global Sanitation Problems?', *Environment International*, 31/3: 433–44.

Letema, S., van Vliet, B. J. M., and van Lier, J. B. (2014) 'Sanitation Policy and Spatial Planning in Urban East Africa: Diverging Sanitation Spaces and Actor Arrangements in Kampala and Kisumu', *Cities*, 36: 1–9.

Lukkarinen, J., Berg, A., Salo, M. et al. (2018) 'An Intermediary Approach to Technological Innovation Systems (TIS)—The Case of the Cleantech Sector in Finland ', *Environmental Innovation and Societal Transitions*, 26: 136–46.

Lundvall, B.-Å. (2007) 'National Innovation Systems—Analytical Concept and Development Tool', *Industry and Innovation*, 14/1: 95–119.

Lüthi, C., McConville, J., and Kvarnström, E. (2010) 'Community-Based Approaches for Addressing the Urban Sanitation Challenges', *International Journal of Urban Sustainable Development*, 1/1-2: 49–63.

Ma, X.-F., Kaldenbach, M., and Katzy, B. (2014) 'Cross-Border Innovation Intermediaries–Matchmaking Across Institutional Contexts', *Technology Analysis & Strategic Management*, 26/6: 703–16.

Markard, J. (2018) 'The Life Cycle of Technological Innovation Systems', *Technological Forecasting and Social Change*.

——, and Truffer, B. (2008) 'Technological Innovation Systems and the Multi-Level Perspective: Towards an Integrated Framework', *Research Policy*, 37: 596–615.

Martiskainen, M., and Kivimaa, P. (2018) 'Creating Innovative Zero Carbon Homes in the United Kingdom—Intermediaries and Champions in Building Projects', *Environmental Innovation and Societal Transitions*, 26: 15–31.

Mazzucato, M. (2018) 'Mission-Oriented Innovation Policies: Challenges and Opportunities', *Industrial and Corporate Change*, 27/5: 803–15.

Moran, M., Guzman, J., Ropars, A. L. et al. (2010) 'The Role of Product Development Partnerships in Research and Development for Neglected Diseases', *International Health*, 2/2: 114–22.

Musiolik, J., Markard, J., and Hekkert, M. (2012) 'Networks and Network Resources in Technological Innovation Systems: Towards a Conceptual Framework for System Building', *Technological Forecasting and Social Change*, 79/6: 1032–48.

Okurut, K., and Charles, K. J. (2014) 'Household Demand for Sanitation Improvements in Low-Income Informal Settlements: A Case of East African Cities', *Habitat International*, 44: 332–8.

Pfotenhauer, S. M., Wood, D., Roos, D. et al. (2016) 'Architecting Complex International Science, Technology and Innovation Partnerships (CISTIPs): A Study of Four Global MIT Collaborations', *Technological Forecasting and Social Change*, 104: 38–56.

Planko, J., Cramer, J. M., Chappin, M. M. H. et al. (2016) 'Strategic Collective System Building to Commercialize Sustainability Innovations', *Journal of Cleaner Production*, 112/Part 4: 2328–41.

Platonova, I. (2013) 'International Development Partnerships and Diffusion of Renewable Energy Powered Lighting Technologies in Off-Grid Communities in Developing Countries: Exploratory Study', *Sustainable Practices: Concepts, Methodologies, Tools, and Applications*, 3: 1591–613.

Ramôa, A., Lüthi, C., McConville, J. et al. (2016) 'Urban Sanitation Technology Decision-Making in Developing Countries: A Critical Analysis of Process Guides', *International Journal of Urban Sustainable Development*, 8/2: 191–209.

Reymond, P., Renggli, S., and Lüthi, C. (2016). Towards Sustainable Sanitation in an Urbanising World, Sustainable Urbanization, Mustafa Ergen, *IntechOpen,* doi: 10.1016/j.respol.2018.10.005.

Robinson, D. K. R., and Mazzucato, M. (2018) 'The Evolution of Mission-Oriented Policies: Exploring Changing Market Creating Policies in the US and European Space Sector', *Research Policy*.

Romijn, H. A., and Caniels, M. C. J. (2011) 'Pathways of Technological Change in Developing Countries: Review and New Agenda', *Development Policy Review*, 29/3: 359–80.

Sandén, B. A., and Hillman, K. M. (2011) 'A Framework for Analysis of Multi-Mode Interaction Among Technologies with Examples from the History of Alternative Transport Fuels in Sweden', *Research Policy*, 40: 403–14.

Schot, J., and Steinmueller, W. E. (2018) 'Three Frames for Innovation Policy: R&D, Systems of Innovation and Transformative Change', *Research Policy*, 47/9: 1554–67.

Shou, Y., and Intarakumnerd, P. (2013) 'The Roles of Intermediaries in Sectoral Innovation Systems and Clusters in China and Thailand : An Overview', *Asian Journal of Technology Innovation*, 21/S2: 1–6.

Sixt, G. N., Klerkx, L., and Griffin, T. S. (2018) 'Transitions in Water Harvesting Practices in Jordan's Rainfed Agricultural Systems: Systemic Problems and Blocking Mechanisms in an Emerging Technological Innovation System', *Environmental Science & Policy*, 84: 235–49.

Stadtler, L., and Probst, G. (2012) 'How Broker Organizations Can Facilitate Public–Private Partnerships for Development', *European Management Journal*, 30/1: 32–46.

SuSan, A. (2008) Towards more sustainable sanitation solutions <https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/267> accessed 14 Feb 2019.

——. (2019). Hompage <https://www.susana.org/en/> accessed 14 January 2018.

Suurs, R. A. A., and Hekkert, M. P. (2009) 'Cumulative Causation in the Formation of a Technological Innovation System: The Case of Biofuels in the Netherland s', *Technological Forecasting and Social Change*, 76/8: 1003–20.

Szogs, A., Cummings, A., and Chaminade, C. (2011) 'Building Systems of Innovation in Less Developed Countries: The Role of Intermediate Organizations Supporting Interactions in Tanzania and El Salvador', *Innovation and Development*, 1/2: 283–302.

Tigabu, A. D., Berkhout, F., and van Beukering, P. (2015) 'Technology Innovation Systems and Technology Diffusion: Adoption of Bio-Digestion in an Emerging Innovation System in Rwand a', *Technological Forecasting & Social Change*, 90: 318–30.

Tilley, E., Lüthi, C., Morel, A., Zurbrügg, C. et al. (2008) Compendium of sanitation systems and technologies. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Dübendorf, Switzerland <https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/schwerpunkte/sesp/CLUES/Compendium_1st/Compendium-Final.pdf> accessed 14 Feb 2019.

van Lente, H., Hekkert, M., Smits, R. et al. (2003) 'Roles of Systemic Intermediaries in Transition Processes', *International Journal of Innovation Management*, 07/03: 247–79.

van Welie, M. J., Truffer, B., and Yap, X. S. (2019) 'Towards Sustainable Urban Basic Services in Low-Income Countries: A TIS Analysis of Sanitation Value Chains in Nairobi', *Environmental Innovation and Societal Transitions*.

Wanzenböck, I., Wesseling, J., Frenken, K. et al. (2018) 'A differentiated approach to mission-oriented innovation policy: Contextualizing societal challenges in a problem-solution space'. Paper presented at the EU-SPRI, ESIEE, Paris, 6–8 June 2018.

Watkins, A., Papaioannou, T., Mugwagwa, J. et al. (2015) 'National Innovation Systems and the Intermediary Role of Industry Associations in Building Institutional Capacities for Innovation in Developing Countries: A Critical Review of the Literature', *Research Policy*, 44/8: 1407–18.

Weber, K. M., and Truffer, B. (2017) 'Moving Innovation Systems Research to the Next Level: Towards an Integrative Agenda', *Oxford Review of Economic Policy*, 33/1: 101–21.

Yin, R. K. (2014) *Case Study Research: Design and Methods*, 5th edn. Thousand Oaks, CA: SAGE Publications.