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Roadmap for Innovators in the Process of Innovation for Development

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Abstract: This study aims to provide valuable insights into the process of innovation for development. We selected the "Reinvent the Toilet Challenge", an initiative of the Gates Foundation, with the objective of creating sustainable sanitation solutions for the 2.5 billion people across the globe who lack access to safe and affordable sanitation. The Naturally Acceptable and Technologically Sustainable (NATS) team at the Asian Institute of Technology (AIT), Thailand was appointed by the Gates Foundation to serve as an innovative fecal sludge management (FSM) hub in Southeast Asia and collaborate with other researchers in the region, as well as with other teams from around the world to develop innovative FSM techniques that can help to solve the world sanitation problem. By gaining insights into how innovators interact with key stakeholders, we can understand the process of innovation for development and the role of innovation brokers in the innovation process, and then suggest a roadmap from the perspective of responsible research and innovation (RRI) to guide innovators, project leaders, industry partners, local government, and policy makers in the process of innovation for development.

Keywords: innovation management; innovation process; innovation for development; user and stakeholder engagement; responsible research and innovation

Citation: Koottatep, T.; Sukavejworakit, K.; Virasa, T. Roadmap for Innovators in the Process of Innovation for Development. *Sustainability* **2021**, *13*, 84. https://dx.doi.org/10.3390/su13010084

Received: 30 October 2020
Accepted: 20 December 2020
Published: 23 December 2020

1. Introduction

There has been a growing recognition of the valuable role that fresh ideas and innovation can play across a range of development challenges. Granting agencies in developed countries such as the U.S.A., U.K., and Canada are using challenge-led, competitive funding to identify and support innovative approaches to intractable problems. The granting agencies will typically support proof of concept work for a new idea, and in some cases, will help to translate the concept onto an industry scale. The recipients of these grants include academics, NGOs, start-ups, and social enterprises.

In the corporate world, approaches to innovation have also been changing dramatically. Whereas innovation used to be based on internal R&D, it is now increasingly based on open innovation and leveraging the capability of others. This new paradigm of open innovation has been widely recognized since the published work of Henry Chesbrough in 2003 [1,2]. The works of leading thinkers in innovation processes such as Rothwell [3], Christensen [4], Utterback [5], and Tidd and Bessant [6] can help to shape and refine the corporate innovation process, with consequent improvements in the effectiveness of delivery and resource management.

Innovation has become increasingly important for sustainable development as well as market competitive mechanisms [7]. Large companies as well as governments around the globe view innovation as solutions for societal challenges such as health and wellbeing, ageing populations, food security and sustainable agriculture, sustainable energy, sustainable transport system, resource efficiency and climate change, and inclusive and reflective societies [8,9]. The increasing dependency of society on research and innovation to solve

the problems leads to increasing uncertainty of the future consequences of research and innovation. Irresponsible innovation may lead to negative impacts and economic loss in the innovation process due to unethical actions, lack of governance, and lack of responsibilities of actors in the innovation process [7,8]. The European Commission (EC) has introduced a framework for responsible research and innovation (RRI) as a part of its strategy to prevent negative consequences of irresponsible innovation. Implementing RRI requires an interactive process and collaboration of innovators, businesses, social actors, research funders, and policy-makers in order to find solutions for societal challenges [8]. However, academic literature has shown that industries are not aware of negative consequences and have no knowledge of the concept of RRI [10–12].

In the process of innovation for social and well-being development, resources are significantly constrained, but the range of issues to be dealt with are more complex as with, for example, intellectual property (IP) management in the context of achieving the type of global access sought by many funders. In many sectors, it is the environment in which the innovator has to operate that is complex. The environment may be, for instance, highly regulated, with governments likely to be involved across a whole range of agencies dealing with health, the environment, and so on. In addition, these agencies may not be familiar with the role that innovation can play; therefore, the innovator may encounter barriers to change.

The process of innovation for development is relatively less understood as well as being more demanding and complex than corporate innovation. In addition, many leaders embarking on innovation for development projects are relatively unprepared for the obstacles that lie ahead and there are few resources at their disposal to tackle them. With the exception of the Stanford Global Health Innovation Guidebook [13] of 2013, there does not seem to be a clear roadmap for innovators, nor any clear articulation of the specific obstacles and pitfalls that exist in the process of innovation for development. The study of digital e-health startups by Oftedal et al. [12] also confirms that the four key elements of the concept of responsible research and innovation (RRI): (1) inclusiveness to gain public acceptance and diversity of insights; (2) anticipation about critical issues and new possibilities; (3) reflexivity of assumptions and values; (4) responsiveness to societal values are not sufficiently investigated in the process of innovation for development.

This study aims to provide valuable insights into the process of innovation for development. We selected the "Reinvent the Toilet Challenge", an initiative of the Gates Foundation, with the objective of creating sustainable sanitation solutions for the 2.5 billion people across the globe who lack access to safe and affordable sanitation. The Naturally Acceptable and Technologically Sustainable (NATS) team comprised professors, innovators, and researchers from the Asian Institute of Technology (AIT), Thailand as the project case. The team was appointed by the Gates Foundation to serve as an innovative fecal sludge management (FSM) hub in the Southeast Asia region, collaborating with other researchers in the region and with other teams from around the world to develop innovative FSM techniques that can solve the world's sanitation problems.

As an example of an integrated system, FSM engages many stakeholders in the utilization of research and innovation. The FSM components are specifically the emptying, collection, transportation, treatment, and disposal of fecal sludge. Technology designs and options for user interfaces or onsite collection and storage methods to reduce sludge volumes are key considerations in innovation development. A functioning FSM service chain requires strong awareness and understanding of the consequences of misconduct by households, fecal sludge collectors, fecal sludge treatment operators, related local government officers, and policy-makers at local, provincial, and national levels.

By gaining insights into how innovators interact with key stakeholders, we can understand the context of innovation management and suggest a clear roadmap to guide the innovators, project leaders, industry partners, local governments, and policy-makers who will participate in the process of innovation for development. The roadmap can also be used as guidelines for managing innovation for development projects in other sectors.

2. Theoretical Background

2.1. Innovation Process and Management

The innovation process is a term that describes the various steps involved in converting information into marketable solutions. Jacobs and Snijders [14] described the innovation process as a step-by-step approach to selecting concepts, developing them and eventually transforming them into new innovations. The innovation models that have been developed typically follow a process of generating ideas, exploring possibilities and identifying needs. This process was described as divergent by Van der Ven et al. [15]. Once an idea has been selected, the next step involves processing it into something tangible that can then be marketed. Typically involving the creation and testing of prototypes, this development process is considered to be convergent behavior [15]. Once the newly developed product, process or service passes this step, it is ready to be introduced to the market. The implementation or launch of the new innovation involves preparing customers through marketing activities. The next step after the launch is the post-launch phase, which is a period of explicit learning. The aim here is to ensure the innovation is sustained and supported, which may require reinventing it to match demand or scaling it up when the demand is high. In this respect, the learning that takes place is not only about the innovation itself, but also about the innovation process [6].

Drafted in 2013 by a global health research team from Stanford University, The Global Health Innovation Guidebook [13] identified six steps that are crucial to success in global health innovation project management, but which consistently create roadblocks for innovators. Figure 1 illustrates the six steps of the global health innovation process, which are also applicable for the context of innovation for social and well-being development.

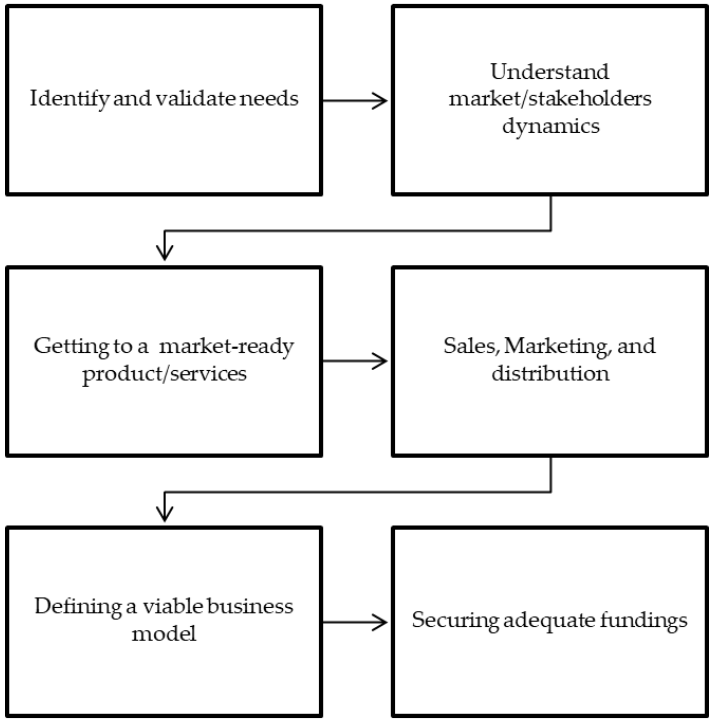

Figure 1. Six steps in process of innovation for development (adapted from Stanford Global Health Innovation Guidebook [13]).

Aligning with the *Identify* phase of the innovation process, the first steps from The Global Health Innovation Guidebook focus on finding and understanding a need. Fortunately, university programs and courses are now available that support the activities in this phase by creating better understanding of designing and prototyping in the early stage of innovation development. However, things become less clear in the *Invent* and *Implement*

phases of the process. During the *Invent* phase, the focus is on understanding how the stakeholders who will be affected by the innovation obtain maximum value from it, while the activities in the *Implement* phase are aimed at ensuring that value is delivered.

Although it may appear that the innovation process follows a linear flow of sequential steps, it is important to understand that this is not the case in reality. There can be a great deal of repetition, particularly during the *Invent* and *Implement* phases, when there is often interaction between various aspect of the planning and implementation. It can often be necessary to take a step back in the process to revise and reevaluate whenever fresh information comes to light.

Effective management of the innovation process is essential, but it comes with risk and uncertainty. Managing the innovation process primarily involves adapting the various elements to enhance quality and efficiency while also reducing the time involved and the potential for failure. Phasing is useful in this respect because it enables the innovation process to be conceptualized, thereby making it easier to identify potential drivers and roadblocks while also facilitating feedback loops and cycles that help informed management to take place before moving on to the next phase.

Aside from the innovation phases, the innovation process includes contextual factors that consist of organizational strategy, culture, leadership, organizational structure, resources/skills, and links to outside the organization [6,14]. Stanford University's Global Health Innovation Guidebook identified some of the conditions that impact and complicate the innovation process. These include having multiple stakeholders, such as patients, providers, and payers, with each group having its own different although often overlapping interests; the demanding safety and testing requirements enforced by governments and healthcare providers; the variety of settings, each with its particular infrastructure, customs, and market dynamics; and the constraint place on purchasing power, adoption, and collaboration through the lack of financial, physical, and human resources.

2.2. The Ethical Principle of Being Responsible in the Innovation Process

In the business context, managing the innovation process strives for enhancing quality and efficiency, and gaining advantages in competitive markets. The inputs of decision-making processes are based on technical considerations and market potential [16]. Business enterprises mainly focus on minimizing financial risk and maximizing commercial success rates. To gain competitive advantages, they might demonstrate ignorance of ethical and environmental issues, either intentionally or unintentionally [17]. Innovation process models such as stage-gate and open innovation do not embed a decision-making framework to address ethical concerns and dilemmas from various stakeholders' perspectives [18]. As such, not taking ethical aspects into account in the innovation process may lead to negative impacts and economic losses. An example is the case of the electronic patient record system project in The Netherlands. The project was turned down by the Dutch government in 2011 after EUR 300 million had been invested over the previous 15 years due to a privacy issue [7].

Irresponsible innovation may take place from unethical actions, lack of governance, and lack of responsibilities of actors in the innovation process [8]. Von Schomberg [7] viewed negligence of fundamental of ethical principles as a type of irresponsible innovation. This view of irresponsible innovation is reflected in practices where stakeholders were unaware of the importance of societal and environmental context. The costs of being irresponsible are substantial, especially in the implementation phase compared to the design phase. It is essential for all actors participating in the innovation process to be responsible for anticipating and reflecting on both positive and negative impacts of the outcomes of innovations.

To deal with complexity and uncertainty in the innovation process, Iakovleva et al. [19] proposed a conceptual framework of responsible innovation on the firm level. Responsible innovation can be considered as the purpose, process, and outcome of innovation [11,16]. Implementation of responsible innovation on the firm level requires the congruence between

the purpose for the social benefits and outcomes of innovation. To be able to diffuse innovation in a responsible way, its purpose, process, and outcome with regard to ethical and responsible behavior should consider four elements: anticipation, inclusiveness, reflectiveness, and responsiveness [16,19]. Anticipation is necessary in the early stage of innovation activities to figure out those intended and unintended economic, social, and environmental impacts, and to identify ethical issues. Inclusion with the involvement of various stakeholders in innovation activities would help the development of perceived ownership of the innovation outcomes and motivate creativity. Reflection on underlying purposes, motivations, and unintended impacts encourages partnership or collaboration among internal and external knowledge networks. Responsiveness ensures the ability to demonstrate care and respect towards stakeholders and societal values. Thus, the process of participation and inclusion of relevant stakeholders becomes crucial during the whole activities of the innovation process [19].

2.3. Innovation Brokers and Their Functions in the Innovation System

An innovation broker can help with different aspects of an innovation system, including the formation of a network, managing the innovation process, and offering an institutional perspective. The role of innovation brokers in the innovation process was described by Klekx and Leeuwis [20] as specialized intermediaries [20]. The support provided by innovation brokers can be categorized into three basic functions: (1) demand articulation: identifying and defining where innovation is needed and matching this with technological, knowledge, funding, and policy demands; (2) network formation: bringing together relevant actors through a process of finding, screening and matchmaking cooperation partners; and (3) innovation process management: ensuring the multi-actor network is fully aligned by facilitating their learning and cooperation in relation to the innovation process. These three basic functions are corresponding with the four elements of responsible innovation process [16] as discussed in the previous section. However, innovation brokers need to take social and ethical aspects into consideration while conducting innovation activities, and integrate the innovation process with the purpose and outcome of innovation as suggested in the conceptual framework of responsible innovation [19].

Johnson [21] defined the functions of innovation brokers in terms of their roles, which included mediators/arbitrators, sponsors/fund providers, filters/legitimators, technology brokers, and resource/management providers. However, these definitions of the functions and roles of innovation brokers are somewhat simplified and do not paint the full picture of the many functions they perform. Based on an extensive literature review, Howells [22] identified the following functions performed by innovation brokers: foresight and diagnostics; scanning and information processing; knowledge processing and combination/recombination; gatekeeping and brokering; testing and validation; accreditation; validation and regulation; protecting the results; commercialization; and evaluation of outcomes. How and when these functions are applied are dependent upon the specific requirements of the innovation network across the various phases of innovation development [23].

2.4. Relationships Between Actors and the Institutional Context in the Innovation System

It is widely accepted that it is not possible for a single actor to pursue an organization's innovation goals without the input of other actors due to the need for pooling skills and resources [24]. For this reason, successfully achieving innovation goals, both individual and collective, and acquiring the necessary resources requires a support network, which will vary in size and scope in relation to the innovation process being undertaken [25]. The concept of a support network presumes the need for a core network of voluntary members. However, because it does not automatically follow that the various interests of the network partners are aligned, there is inevitably scope for political maneuvering and negotiation within the network [26]. Additionally, the process is likely to require the support of actors

from outside the network whose participation may not be voluntary but, instead, based on mutual interdependence.

According to Hung and Whittington [27], another requirement in the innovation system of an organization is institutional entrepreneurship, which describes the input of actors with an interest in particular institutional activities and who are able to utilize available resources either to transform institutions or to create new ones. The motivation for these actors is the desire to improve the systems in which they are involved [28]. According to the structuration theory of Giddens, there is a dual relationship between the actors and the structures in which they operate because the "structural properties of social systems are both medium and outcome of the practices they recursively organize". In other words, social practices follow a pattern that reflects a "virtual order" composed of the rules, resources, and transformative relationships that both restrict and facilitate social activities.

In previous studies of innovation systems, the term "mutual embeddedness" has been applied to describe the reflexive relationship that exists between actors and the institutional contexts in which they operate [29]. In this relationship, the actors reflexively monitor the actions and aspects of the contexts within which they move, considering past, present, and future events with the intention of minimizing any uncertainty in the process of achieving their objectives [30]. In many cases, the objectives of these actors are embodied by articulated visions of exerting influence by guiding, convincing, binding, and mitigating uncertainty [31]. The need to minimize uncertainty is especially significant, because the main actors in the innovation process are exposed to uncertainty in many aspects, such as complementary resource acquisition, the development of consumer demand, policy and legislative adversity or instability, and the actions of network partners and competitors [32]. Although actors can take measures to control their institutional environment (structure) in an attempt to mitigate uncertainty, their influence is inevitably restricted. The unintended consequences of their own actions or of events beyond their control are significant factors in bounding or conditioning subsequent activities within the innovation system, therefore they represent a vital source of structure variation [28].

3. Materials and Methods

In the present study, an innovation journey model [15,33,34] and event analysis was employed as the research method. Data were collected through semi-structured interviews with actors from across the innovation network and institutional environment. The key informant interviews include the NATS team leader, a senior advisor, the NATS staff and industrial product designers, facilitators of the Gates Foundation, and research funding agencies. The interviews were recorded and transcribed in summary sheets. The study participants not only provided their own personal experiences but also shared their particular perspectives and observations. When conducting this type of analysis at the actor level, it is necessary that external influences also be taken into account, which is not always the case in actor-oriented analyses. The viewpoints of actors from within both the innovation network and the institutional environment were analyzed so that agency–structure interactions could be reconstructed. Due to their ongoing interactions with the environment in which they function, as well as evolving resource requirements and external events beyond their control, innovation networks tend to lack stability and the makeup of their membership is prone to changing throughout their lifespans. Even so, it is possible to identify the core network of innovators and differentiate them from the peripheral actors operating within its environment. These primary data were complemented with secondary data gathered from various internal network documents (e.g., meeting minutes between the NATS team and partners) and external documents (e.g., policy documents). We identified key findings for each source of data and sorted the key findings according to the evaluation objectives. The key findings were compared and contrasted across the data sources for each evaluation objective from more than one data source. Employing a multi-stranded approach enabled triangulation, thereby eliminating the potential for biases in post-factual

accounts and increasing internal validity. Table 1 outlines the data collection methodology employed in this study.

Table 1. Data gathering methodology.

Types of Data Gathering	
Semi-structured interviews aimed at identifying actor experiences and perceptions	Interviews with team leader and Naturally Acceptable and Technologically Sustainable (NATS) staff, civil servants, industry partners, facilitators and funding agencies
Observations of actor interactions	Pilot plant and field visits, steering committee meetings, and workshops with local partners
Document analysis	Analysis of research documents, related literature, and communications with the Gates Foundation

4. Results and Discussion

4.1. Gates Foundation Initiatives and the NATS Team

The Bill & Melinda Gates Foundation (hereafter referred to as the "Gates Foundation") is the world's largest private grant-making foundation. The Gates Foundation has applied the concept of open innovation [1] as a means of discovering innovations and inventions with the potential to support the creation of a fairer world in which everyone enjoys the same opportunities for a healthy and productive life. With a focus on the areas of water, sanitation and hygiene, the Global Growth and Opportunity Division is a part of the Gates Foundation that is committed to supporting the development of innovative products and policies designed to eliminate barriers to economic opportunity, empower individuals to escape from poverty, and provide sustainable and inclusive growth for the benefit of all. Through this initiative, the Gates Foundation partners with actors from both the public and private sectors to tackle urgent global issues while also promoting increased public awareness.

In 2011, the Gates Foundation's Water, Sanitation & Hygiene Program launched the "Reinvent the Toilet Challenge" with the objective of creating sustainable sanitation solutions for the 2.5 billion people across the globe who lack access to safe and affordable sanitation. The Global Growth and Opportunity Division of the Gates Foundation invited research teams around the world to participate in the initiative and submit their proposals with the aim of identifying and supporting innovative products and policies that aligned with the Gates Foundation's poverty reduction objectives.

After the proposal bidding, the AIT team was appointed to serve as a hub of innovative FMS management in Southeast Asia. The initiative would involve collaborating with other researchers across the region in countries such as Vietnam and Cambodia, as well as with other teams from around the world to develop innovative FMS solutions to address sanitation problems across the globe. The principal objective of the project is to develop new decentralized systems and technologies for treating and safely disposing wastewater and human body waste from dwellings and businesses close to their sources. The aim is to accelerate the commercialization of new, high quality, decentralized wastewater treatment systems that can provide the poor, especially those living in urban settings, with vastly improved sanitation solutions. The project was divided into three phases: the creation of a platform for innovation, the design and development of lead options for commercialization, and the accelerated commercialization of the lead options.

From the initiative of the AIT team in 2012 and with a USD 5 million research grant for "Sustainable Decentralized Wastewater Management Systems" from the Gates Foundation, the NATS Lab was established in 2013. From 2013 to 2016, the prototype development and pilot-scale testing of the product concepts were completed, placing them ready for industry-scale development. Currently there are 50 research staff working in the NATS Lab on three innovative product research projects as presented in Figure 2, which include Cess to Fit, the Solar Septic Tank, and the Zyclone Toilet.

Cess to Fit Solar Septic Tank Zyclone Toilet

Figure 2. Prototypes of NATS product innovation (The third progress report on innovative DEWAT technologies, Asian Institute of Technology 2015).

A major benefit of the "Cess to Fit" system is that it is designed to be retrofitted into existing cesspool systems. It collects fecal matter and treats it until it is ready to be released safely into the environment. As the name indicates, the "Solar Septic Tank" collects solar energy, which it then utilizes to eliminate pathogens, enhance the biodegradation of organic matters, and produce better quality septic tank effluent. By halving the amount of accumulated solids compared to conventional septic tanks, it generates significant benefits for both the environment and public health. The "Zyclone Toilet" is able to separate solid and liquid waste through the clever use of gravity and the cyclone concept. The fecal matter is heated to disinfect it and then used as a solid conditioner. The black water is also treated to generate a pathogen-free byproduct which can be reused.

The NATS team is also currently developing another innovative product called the Sanitizer Truck. The solid–liquid separator and disinfection system enhances the efficiency of fecal sludge management while also opening up possibilities for revenue generation through sludge recycling. The entire system is fitted in a truck, therefore its mobility reduces transportation and treatment costs.

4.2. Event Analysis

The timeline of NATS' project milestones, activities, role and responsibilities of the NATS team was identified and summarized in Table 2. As a project leader, the NATS team had clear project milestones for new product development. Following a typical innovation process, the team's process of new product design and development started from an exploration of the market and technology feasibility to inform idea generation. At the early stage, the researchers and innovators generated new ideas from their own technological specializations. Knowledge and experience from previous research projects provided a platform for idea generation and ensuring the NATS team is well-accepted by other stakeholders in present projects. The team members served as "sources of innovation" (playing a major role in initiating and developing innovations). After the innovation had been developed, it was the responsibility of the team to commercialize the innovation by following the Global Access Policy of the Gates Foundation. Then, the team performed the role of "carriers of innovation" (transferring an innovation that does not originate from the particular provider). In this capacity, the team had to evaluate appropriate technology options as well as business formation options when the institutional support from the host university was missing.

Next, several product concepts and prototypes were developed and tested for functionality and practicality. The new products were tested in the field with early adopters in several locations and the innovation options were finalized. When it came to the commercialization phase, it required business development. Without any business background or institutional support, the NATS team faced many difficulties in setting up businesses and

building strategic partnerships for market penetration. In addition, market development through policy advocacy from local governments was indispensable.

Table 2. Timeline of NATS' project milestones and activities.

Timeline	Project Milestones	Important Activities and Events	Role and Responsibilities of the NATS Team
2011		Proposal bidding	Team up with partners in Thailand, Vietnam, and Cambodia
2012	Project started	Grant contract signed up	Idea generation Contract and agreements
2013	Mobilization	Established NATS Lab at the Asian Institute of Technology (AIT)	Idea screening and field research to explore unmet needs
2014	Product concepts	Prototype developed and lab-scale testing	Design and development
2015	Product design	Field testing and industrial design	Finalize innovation options
2016	Process design	Manufacturing and pilot-scale experiment Press conference in May 2016	Seeking industry partners, costing and pricing
2017	Business formation	Industry scale-up and partnerships	Founding team, business deals, legal arrangements, commercialization strategy
2018	Business startup	Business and policy advocacy	Entrepreneurial action, business execution

The challenges faced by the NATS team include its relationships with the institutional support mechanism, with the Gates Foundation, and with AIT as the host university, applying innovation management with a system approach, the nonexistence of market mechanisms in the Southeast Asia region, and generating a business model with social development goals. Van de Ven [33] pointed out that the complexity of interactions in innovation processes keep growing due to the involvement of multiple players and the heterogeneity of customer demands. It indicates that the innovation journey is unpredictable as a result of a nonlinear cycle of divergent and convergent behavior. Oeij, Torre, Vaas, and Dhondt [34] applied the innovation journey model of Van de Ven [15] to understanding the social innovation process. The research concluded that six paths which could lead to the adoption of social innovation were used in the innovation journey: (1) power-based design to obtain financial and political support; (2) filling a gap; (3) self-reliant empowerment; (4) incremental progress; (5) powerful people and leadership; and (6) resilient goal-achieving. However, different paths can lead to similar outcomes. While facing these challenges, the roadmap will help project leaders to guide the team through each stage of the process and show them how to overcome the obstacles they are likely to face.

4.3. Relationships Between NATS Team and the Institutional Supports

Since completing pilot-scale and field testing in 2015, the NATS team has struggled with pre-commercial activities because there is no institutional infrastructure, or technology licensing offices (TLOs) and professionals to advise them or help prepare the necessary legal and business contracts. The team has to take on the full risk of product testing and independently reaching out to the industry.

Concerning the Institute's research orientation and the availability of resources, the President of AIT decided not to invest in setting up TLOs. The NATS team then proposed running the program as an independent unit, which would facilitate the process of managing research utilization and dealing with industry partners without any constraints from the administrative process of the Institute. Having received agreement and an approval memo from the President, the NATS research team under the guidance of its project leader, a senior professor, and a researcher, established a company named Inc^2 Co., Ltd. at the Innovation Incubator of the Thailand Science Park to manage the intellectual properties

of the new technologies on behalf of the Institution and deal directly with the business partners.

To turn product innovations into marketable products, the company aims to license the current technologies and persuade the industry to invest in manufacturing and commercializing the products with research and technical support for the NATS Lab. To this end, the company approached several large manufacturing companies in Thailand and overseas in order to transfer the technologies. Several companies and government agencies in Thailand and in other SEA countries expressed a strong interest in both the initiative and the product innovations. One Chinese company would like to license the Solar Septic Tank technology with the aim of further improving it and producing it commercially in China. However, due to its lack of business experience and financial constraints, the company is facing difficulties in dealing with potential partners, especially because the technology transfer process must comply with the Global Access Policy of the Gates Foundation.

4.4. Relationships with the Foundation and the Host University

The Gates Foundation makes significant contributions to the development of global health through grants and funding as well as through its influential policy. The Global Access Policy was developed by the Foundation with the aim of ensuring that its funded projects deliver the intended benefits to their target populations. The two primary requirements of the Global Access Policy are the prompt and widespread dissemination of the knowledge and information learned from foundation-funded projects, and ensuring the affordability, availability, and accessibility of foundation-funded developments to the target populations. In terms of technology and new product development, the Gates Foundation emphasizes the need to address the issue of many existing cost-effective technologies not reaching the target populations due to poverty or failures in the relevant health system [35].

In addition, technology and innovation diffusion require strong collaboration from both within and outside of organizations. To commercialize products, many universities have established supporting units, such as technology licensing offices, innovation centers, and business incubators, under a central administration in order to facilitate the utilization of the works of inventors and researchers. The aim is to generate a new source of revenue from the returns on the research investments. Poh Kam et al. [36] pointed out that the commercialized activities of universities in Asia are limited and have been managed ineffectively with a lack of expertise or strong industry engagement. To solve these problems, technology licensing offices (TLOs) have been established in many universities and these are expected to support investors and researchers in utilizing and translating their research outputs into industry-ready products. However, the existing support systems are perceived by faculties, inventors, and companies as a barrier rather than a support system.

4.5. Innovation Management with System Approach

Fecal sludge management (FSM) is an integrated system that engages many stakeholders in the utilization of research and innovation. The stages of the FSM process involve emptying, collecting, transporting, treating, and disposing of fecal sludge. The key considerations in the development of innovation to improve this process focus on designing technological solutions that enhance the user interface or reduce sludge volumes by creating better onsite collection and storage methods. The complete sanitation service chain is shown in Figure 3. Functioning FSM service chains require strong awareness and understanding of the consequences of misconduct by households, fecal sludge (FS) collectors, FS treatment operators, related local government officers, and policy makers at local, provincial, and national levels.

A study carried out by the NATS team in Thailand revealed that the volume of domestic wastewater produced every day is 20 million cubic meters. Of this daily volume, 1.6 million cubic meters of wastewater passes through sewer networks to treatment plants that often do not work. The data on fecal sludge in Thailand are also worrying. The NATS

research team found that of the 60,000 tons of fecal sludge collected every day, only 4500 tons, or less than 10 percent, undergoes the necessary treatment.

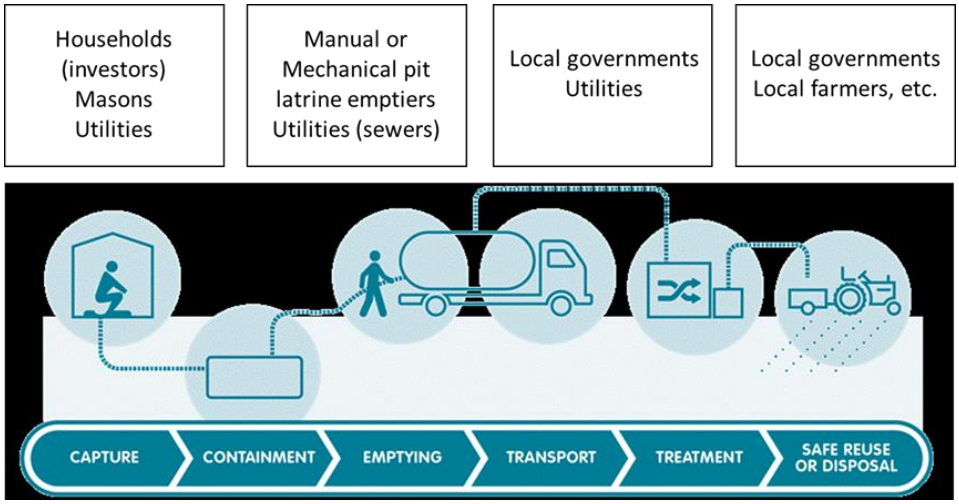

Figure 3. Sanitation and fecal sludge management service chain (source: adapted from [37]).

According to the statistical reports of the Department of Health, more than 80 percent of Thai households have installed and use proper latrines for their daily needs. However, most of the households report unclear understanding about the disposal and services of FS collection and treatment. There is no database for local authorities to track the situation and no monitoring system has been put in place. Inefficiency in FS waste treatment and a lack of law enforcement are the major issues contributing to contamination and environmental problems. The study by the AIT research team shows that inefficiency comes from a lack of motivation among collectors due to mismanagement and inadequate financial returns as well as a lack of awareness among local operators and local governments. The FS collectors normally operate the service when called out by the customers without proper route planning or calculations of maximized returns. The collectors often believe that the cost of operating in accordance with the law is greater than their earnings from the FS collection service. Hence, they are willing to dump FS into natural water sources rather than delivering it to the treatment sites.

4.6. Factors Affecting the Market Mechanisms and Business Model Development

In terms of commercializing product innovation in FSM, the market mechanisms are not a key driver of innovation adoption. Many factors affecting the links in the FSM service chain were identified by Strande et al. [38], who observed that users at the household level could not afford professional emptying services; collection and transport trucks could not access many houses that were located along narrow lanes and paths; transporting FS long distances to treatment facilities was too expensive for many operators; and there was a shortage of appropriate FS discharge functioning locations and treatment facilities. Due to the lack of awareness and motivation among end users and the absence of incentives for operators in the FS management system, it is unlikely that the NATS team will be able to develop a viable business model.

Based on the current situation, the startup company (Inc^2) has to consider the option of setting up the industry standards and stimulating FM policy implementation. It is unlikely that a product's innovativeness alone with be sufficient for it to gain acceptance from the markets because it would require end users or inhabitants in developing countries to change their usual behavior from non-latrine usage to latrine usage and to invest in the new products. People in rural areas tend not to be aware of the social impacts and consequences of water contamination from improper FS disposal and treatment, such as diarrhea. Changing the mindsets of rural people and local administrators requires the

NATS team to perform the role of policy advocates in a campaign designed to make policy makers take notice and then take action.

5. Conclusions

This study expands our understanding of the roadmap used to guide innovators in the process of innovation for development. The concept of innovation journey and the concept of RRI were used as a framework of analysis and supported the discussion. The analyses of the case study provide insights into the different roles of innovators as innovation brokers, such as the leading role of subject specialization at the regional level, innovative entrepreneurs in commercialization, or policy advocacy in driving changes in the social context. The findings show that the NATS team performs multiple roles of an innovator in the system of innovation for development. These roles include: (1) the leading role of subject specialization at the regional level; (2) the role of innovator in new product development; (3) the role of innovative entrepreneurs in innovation dissemination and commercialization; and (4) the role of policy advocacy in driving changes in the social context.

According to Geels and Schot [30], there are various factors influencing innovation, including the preferences of consumers, government policies, and variations within the market at regional, national, and global levels. To create an environment that is conducive for local translation, it is necessary to have tangible visions and actors able to operate across boundaries to perform innovation brokerage roles. Innovation brokers must be able to re-interpret the contexts in which they operate continuously, even though they are unable to exert any significant influence on these contexts. The solution to overcome the systemic problems of FSM requires an integrated system-level approach that addresses all of the steps in the service chain and incorporates technology, management and regional and national planning.

The suggested roadmap to guide innovators through the process of innovation for development presents the six steps of the innovation process, and is shown in Figure 4. The case of NATS reveals the areas on which to focus in the process of innovation for development. These include the needs of key stakeholders as well as users, the requirements of providers, agency, industry standards, building relationships with industry partners and local government, distribution and sales strategies, applying a hybrid model with business and social development goals, and securing sufficient resources in the implementation phase. The key considerations in managing the process of innovation for development include building relationships with multiple stakeholders, using different perspectives in product design and development, not necessarily needing to build a company, going either downstream or upstream, using a hybrid business model, and being able to demonstrate the impact.

5.1. Theoretical Implication

The findings of this research expand our knowledge of innovation journey and the concept of RRI. The NATS project showed a high degree of intuitive awareness of responsibility despite limitations of the ability to involve all stakeholders. This supports the conclusion of Oftedal et al. [12], that startups intuitively integrate inclusiveness and reflexivity into their practices. The case analysis identified how the awareness moved from low level to full awareness in the innovation process. The inclusion of external stakeholders was taken at the early stage of innovation process. In contrast to previous literature in existing firms, this study supports the core principle of RRI and applicability of the concept in the context of startups [12,39,40].

5.2. Practical Implication

The findings from the NATS Project suggest a pathway for actors in the innovation process. The governance framework and multi-stakeholder strategy is necessary for managing the innovation process. Policy-makers and research funders may consider using both

top-down and bottom-up approaches in enhancing context awareness as well as strategic awareness, and collaboration of all stakeholders for gaining insights and societal values. According to the maturity model [11], with more knowledge and awareness of research and innovations, the more strategically and effectively it can be employed [41]. Building on multiple case studies, we can develop the findings of the studies into an innovation for development guidebook and management tools. For capacity building, we can bring in practitioners from different fields to learn how to manage the innovation projects from real experiences through workshops and training programs. This can lead to network development for future collaborations in new development project initiatives.

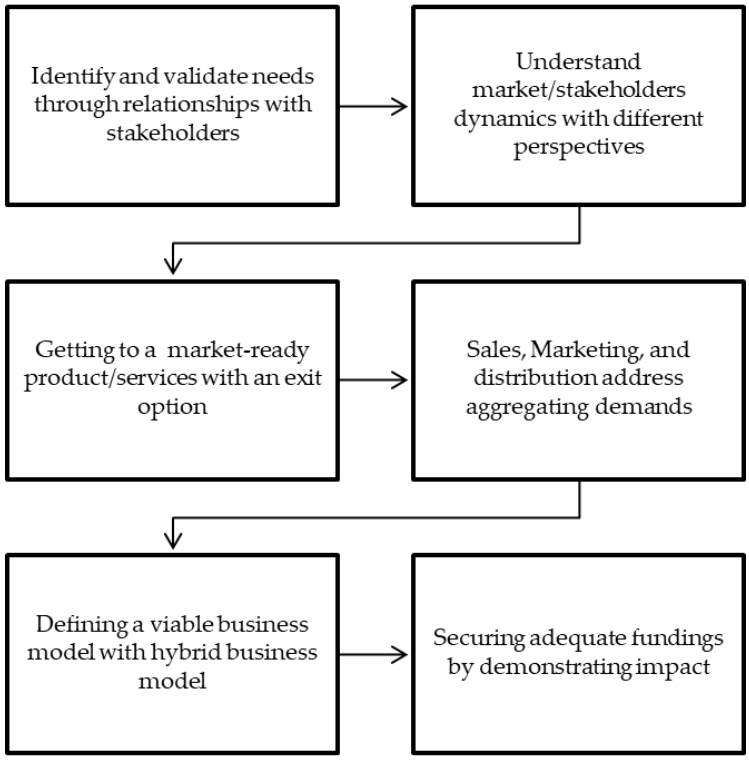

Figure 4. Suggested roadmap for innovators in the process of innovation for development.

5.3. Research Limitation and Future Research

This study is a single case study and although it is useful to explore the concept and practices, it limits generalizability of the suggested roadmap. For future research, we can use this roadmap to explore insights from multiple case analysis. Selected cases of innovation projects for development of different global issues such as agricultural development, water and hygiene, global education, financial services for the poor, and gender equality will provide more understanding and insights into the innovation process.

Author Contributions: Conceptualization, T.V. and T.K.; methodology, T.V.; validation, T.V., T.K. and K.S.; formal analysis, T.V.; investigation, T.V.; data curation, K.S.; writing—original draft preparation, T.V.; writing—review and editing, T.V. and T.K.; visualization, T.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data presented in this study are available on request from the corresponding author and with the permission of Asian Institute of Technology and the Gate Foundation.

Conflicts of Interest: The authors declare no conflict of interest.

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