Doing good by doing new things with others: insights into developing sustainability-oriented innovations in the agri-food value chain

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1. Introduction

Technology developers, technology vendors, policy makers and academia are actively exploring how emerging "Industry 4.0" technologies can contribute to sustainability. However, despite the promise of these emerging technologies, many emerging technologies such as blockchain and artificial intelligence have not yet a clear practical application in industry (Olsen and Tomlin, 2020), let alone a practical contribution to sustainability.

To make a sustainable impact, sustainability-oriented innovations (SOIs) often need to go beyond firm boundaries, including a wider ecosystem where multiple actors introduce new business models, products and services which they could not have introduced alone (Adams et al., 2016). To date, management literature does not provide much empirical insights on how firms can collaboratively improve sustainable performance by leveraging upon "Industry 4.0" technologies. This gap in literature may hinder the managerial decision making process.

Adopting an action research approach, we study the collaborative adoption of "Industry 4.0" technologies for sustainability in the agri-food sector. The agri-food sector is one of the few industries in which several actors collaboratively start to use "Industry 4.0" technologies (Stanco et al., 2020). We find that three factors can drive the collaborative adoption of such technologies, namely (1) a demand for technological solutions (market pull), (2) opportunities for new business cases as a result of technological developments (technology push) and (3) sub-optimal value chains due to frictions between the actors' behaviour and the business case and/or the adopted technology (behavioural pull). Regardless of the driver, our findings suggest that firms benefit from creating an in-depth understanding of the behavioural, technical and business case aspects prior to developing the SOI. These insights contribute to the body of literature on innovation processes such as the design thinking process and the social innovation process.

The remainder of this paper is organized as follows. Chapter 2 discusses literature on collaborative SOIs and the adoption process of "Industry 4.0" technologies with a focus on the agri-food industry. Chapter 3 present the action research approach and chapter 4 presents the results. Finally, chapter 6 discusses the findings and provides the conclusions of this research.

2. Literature review

A wide variety of definitions of SOIs exists. However, although no unified definition of SOIs exists, there is a shared understanding between the definitions proposed in the literature. Adams et al. (2016) define SOIs as '[SOI] involves making intentional changes to an organization's philosophy and values, as well as its products, processes or practices, to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns' (p. 181). Bos-Brouwers (2010) define sustainable innovation as 'innovations in which the renewal or improvement of products, services, technological or organizational processes not only delivers an improved economic performance, but also an enhanced environmental and social performance, both in the short and long term' (p. 419). Tello and Yoon (2008) define sustainable innovation as 'the development of new products, processes, services and technologies that contribute to the development and well-being of human needs and institutions while respecting the world's natural resources and regenerative capacity' (p. 164). In this paper, we adopt the definition of Adams et al. (2016). Adams et al. (2016) proposes a three-stage model to classify SOIs as depicted in figure 1.

Figure 1 – The three stages of SOIs – adopted from Adams et al. (2016)

	1. Operational optimization doing more with less	**2. Organizational transformation doing good by doing new things**	**3. System building doing good by doing new things with others**
Innovation objective	Compliance and efficiency	Novel products, services or business models	Novel products, services or business models that are impossible to achieve alone
Innovation's relationship to the focal firm	Incremental improvements to business as usual	Fundamental shift in firm purpose	Extends beyond the firm to drive institutional system change

In the first stage, operational optimization, SOIs aim to optimize the environmental and social value of business as usual. From a technological perspective, operational optimization SOIs provide 'technical fixes' based on incremental improvements of existing technologies. External collaboration is typically limited to involving knowledge experts such as technology providers and consultants to help navigate and implement the SOI (Adams et al., 2016).

In the second stage, a more fundamental shift in the firm's purpose is made as SOIs aim to develop novel products and services or to adopt novel business models based on, for example, the circular economy, biomimicry and frugal innovation. This results in more radical technological innovations. Furthermore, although SOIs remain largely oriented on the focal firm, it typically requires firms to develop long-term collaborations with immediate stakeholders such as (new) buyers and suppliers (Adams et al., 2016).

In the third and final stage, SOIs extend to the system level rather than the individual firm level to create sustainable value. System building SOIs (sb-SOIs) acknowledge that sustainability is not an attribute of a single firm, but rather, is created collaboratively with multiple actors. These actors are often not directly connected to the focal firm (e.g. NGOs, industry associations, actors from other industries and buyers and suppliers beyond the first tiers of the supply chain) (Adams et al., 2016).

Although there is no clear path on how to implement sb-SOIs with multiple value chain actors, several developments such as the adoption of “Industry 4.0” technologies to enable traceability and precision farming are predicted to play a major role in sustainable farming in the future (Stanco et al., 2020).

2.1. Requirements for the adoption of “Industry 4.0” technologies

For firms to adopt new technologies, literature stresses the importance of fitting the technology with (1) economic and strategic factors, (2) operational and supply chain factors and (3) organizational and behavioural factors. In the absence of a fit, firms are unlikely to adopt the new technology, regardless of the capabilities offered by the technology (Maghazei et al., 2022). Maghazei et al. (2022) suggest that the three fits can be achieved in an iterative manner while the technology adoption evolves from a use case to fully implemented solution. The next sections elaborate on each of the three fits in more detail.

1.2.1. Technological fit with economic and strategic factors

The first fit refers to the (potential) economic impact and the strategic relevance of the new technology (Maghazei et al., 2022). This fit may rely on developing a “business case” as well as financial measures such as the return on investment (ROI), the payback period and the internal rate of return (IRR). Firms can invest in the new technology when the revenue or cost savings generated by the new technology is higher than the costs of capital (Maghazei et al., 2022). However, firms should avoid to solely rely on financial measures as they may fail to capture long-term benefits, tacit benefits (e.g., organizational learning) and strategic advantages while they may risk to overstate short-term costs such as implementation costs, short-term productivity dips and costly training Beatty and Gordon, (1988) and Chew et al. (1991). In fact, the managers in the study of Maghazei et al. (2022) on the implementation of drones in operational environments could often not provide rigorous evidence of the ROI for their potential applications. Instead, they could envision multiple functional benefits (e.g., the ability to quickly reach inventory stored at high levels, inspect machines from a bird's eye view, and perform routine surveillance). Hence, the economic benefits are usually rather speculative.

Based on the insights derived from the literature presented above, to implement new technologies in a collaborative manner with multiple actors, the sb-SOI should result in economic impact and strategic relevance for all involved actors, at least at a speculative level.

2.2.2. Technological fit with operational and supply chain factors

The second fit, also known as "process integration" refers to the need to fit the technology with the firm's operating model (Das and Narasimhan, 2001). Process integration is particularly important when the technology affects routines, responsibilities and reporting channels (Meredith, 1897). Firms can arguably achieve a fit between the new technology and their operating model in two ways namely that the technology can be adjusted towards the operating model or vice versa. In the later case, Duimering et al. (1993) suggest to adjust the operating model both prior and during the implementation process. Process integration typically becomes more visible once pilot implementations have been initiated and may be more difficult to spot beforehand (Meredith, 1897). This may be especially true once the technology affects the operating model of multiple organizations.

2.2.3. Technological fit with organizational and behavioural factors

User acceptance is an important element for the adoption of new technologies. In fact, a large body of literature has studied the organizational and behavioural factors in relation to technology adoption. For example, training employees before and after the implementation of technologies likely contributes to the effectiveness of the new technologies. Likewise, Bala and Venkatesh (2016) found that investing in change management resulted in increased technology adoption. Finally, research on the sociotechnical systems highlight the importance of the "human" fit rather than just hardware and business considerations (Trist, 1981). This is of particular importance when the new technologies expose individuals to significant risks and uncertainty (Loch, 2017; Roscoe et al., 2019) which may be particular relevant for emerging "Industry 4.0" technologies.

2.2. The process of adopting "Industry 4.0" technologies in sb-SOIs

Management and innovation literature offers a rich body of knowledge on co-creating innovations with multiple actors. For example, the integration of suppliers and customers in the innovation process (Zhou et al., 2014), the impact of structural characteristics of the value chain on the innovation (Potter and Wilhelm, 2020), the role of social capital (Koufteros et al., 2007) and the role of network ties and supplier-degree centrality (i.e., the number of network ties a firm has with other suppliers and customers) on innovation capabilities (Gao et al., 2015) is well-documented in literature.

However, literature has mainly focused on the first stage of SOIs – the operational optimization – and, to a somewhat lesser extent, the second SOI stage of organizational transformation based on the collaboration with direct buyers and suppliers. This is, for example, evident from the literature review by Chen et al. (2017). Out of the 90 papers surveyed in their literature review on supply chain collaboration for sustainability, only one paper considered the collaboration with competitors (a mathematical paper on the cooperation between recycling firms by Lu et al. (2014) and only one paper considered the collaboration with other stakeholders in the value chain (a case study on public-private relationships for wind power generation by Martins et al. (2011). Likewise, also Adams et al. (2016) mentions that limited attention has been paid to developing sb-SOIs

Sb-SOIs have some typical peculiarities which need to be taken into account in the development process. First, sb-SOIs require the collective involvement of multiple actors to define the problem and search for a solution (Mirata and Emtairah, 2005; Seebode et al., 2012). Second, collaboration and innovation, in itself, is a self-interested process in which actors tend to participate only when it contributes to their own survival and (financial) benefit (Simatupang and Sridharan, 2002). By collaborating together, individual actors can exploit benefits that they cannot create alone (Simatupang and Sridharan, 2002). As such, sb-SOIs need to ensure benefits and shared value propositions for all engaged actors (Adams et al., 2016). Third, the collective action of the sb-SOI most likely requires behaviour change of multiple actors to develop workable relationships and incentives for a wide range of actors such as private, public and civil society partners (Arellano et al., 2021; McDonough and Braungart, 2002; Yan et al., 2018). The behaviour of these actors are often beyond the direct control of the focal firm, but within the sphere of influence (Seebode et al., 2012). Fourth and foremost, sb-SOIs intend to do something *new with others*, rather than optimizing existing activities. This implies that the goal of the technology and the business case are unknown at the start or may only resemble vague ideas and that innovations are rather radical instead of incremental.

In the next sections, we present major innovation processes which can be used to develop sb-SOIs based on “Industry 4.0” technologies.

2.2.1. Design thinking process

Design thinking provides an interesting starting point to guide the development of “Industry 4.0” technologies for sb-SOIs. Design thinking prompts actors to find causes instead of jumping straight into solutions to (imagined) problems. By starting from understanding the problem, design thinking has proven valuable for developing solutions for complex problems and might therefore be useful for developing solutions for the complex problem of achieving combined economic, environmental and social performance with multiple actors at multiple levels of the value chain by adopting new technologies. In addition, design thinking stimulates the actors to consider the problem from multiple angles and to co-create solutions together. In this way, the holistic design thinking process reduces the risks of managerial and organizational biases such as the confirmation bias – i.e. managers and other value chain actors ignore any innovation that is not in coherence with their preferred innovation (Pohl, 2004).

The design thinking process broadly follows the five stages of “understanding”, “defining”, “ideation”, “prototyping” and “testing” (Plattner et al., 2010). In the understanding stage, the team explores the context and the field of opportunity. It is particularly important to understand this from the perspective of the affected, relevant stakeholders. Qualitative research by means of observations, interviews and other immersion techniques accompanied with secondary research (e.g., Life Cycle Assessments, reports and best practice examples) help to achieve a deep understanding. In the second stage, the defining stage, the actors define the goal and the purpose of the sb-SOI based on the insights from the understanding stage. The defining stage is not just about describing the goal per se, but rather about framing the problem from the point of view of the desired outcome for the various stakeholders. In the third phase, the ideation phase, the actors create ideas based on the defined goal. The created ideas are compared with the previously defined goal for the sb-SOI to ensure that the developed solutions are relevant and customized towards the identified needs and fields of opportunity. In the prototype phase, selected ideas are further developed up to a necessary level of detail to communicate the ideas fast to the stakeholders in an understandable manner, for example though creating artifacts from cardboard, glue and pencils or by developing a small pilot version. As such, the prototypes can represent a new product, services, business models and behavioural change. In the final evaluation phase, the prototypes are tested and evaluated with relevant users to collect feedback and to identify which ideas have the highest potential to succeed. An important aspect of the design thinking method is the iterative loops between the different phases. These deliberately iterative loops aim to rapidly develop and test multiple possible solutions to arrive at an optimal one.

Design thinking has been applied to in contexts and goals similar to the Ploutos context and Ploutos goal such as designing new business models (Geissdoerfer et al., 2016) and identifying root causes of poor performance (Land et al., 2021). Moreover, companies such as Google, Airbnb, Apple, Microsoft, PepsiCo and Toyota have design thinking engrained in their innovation processes. Yet, to the best of our knowledge, the design thinking process has not yet been applied to the SOI process (in the agri-food sector).

However, the design thinking process is not without shortcomings (Iskander, 2018) and some major limitations of the design thinking process in the context of SOIs in the agri-food value chain may include:

- The design thinking process dilutes the sb-SOI process into a linear and clean process, assuming that each phase is a logical follow-up of the previous stage. However, design thinking critics argue that the design process is messy, complex and non-linear (Iskander, 2018) but, rather, relies on inductive, searching and discovering activities. This might be particularly true in a context with multiple and diverse actors such as is the case for the sb-SOI process in the agri-food sector.
- The designers act as gatekeepers for understanding, defining and ideation, which narrows the potential for innovation as former experiences of the designer might bias the type of SOIs considered. Hence, when designers are in the privileged position to interpret the challenge and the fields of opportunity and define the goal of the sb-SOI, while the sb-SOI is only tested with the stakeholders in the prototyping stage, the risk of overlooking meaningful SOIs is considerable (Iskander, 2018). This might be particularly true when sb-SOIs address the need of a diverse set of stakeholders which are interconnected in the complex agri-food network where it is important to consider the boundary conditions.
- Design thinking does not directly include sustainability and may favour non-sustainable innovations over sb-SOIs when non-sustainable solutions are deemed more desirable by the stakeholders.

- Design thinking is resource and time intensive, requires multiple actors to work together and often requires dedicated workspaces. This is especially problematic when multiple stakeholders are involved (Hasso Plattner Institut, 2014) such as for the SOIs in the agri-food value chain.

In sum, while design thinking has much to offer to the SOI process in the agri-food value chain, to apply design thinking successfully, adjustments are inevitable and other perspectives are needed.

2.2.2. Social innovation process

Social innovation can be defined as 'a process of change emerging from the re-combination of existing assets (from social capital to historical heritage, from traditional craftsmanship to accessible advanced technology), the aim of which it to achieve socially recognized goals' (Manzini, 2014, p. 57), through 'a constellation of design initiatives geared towards making social innovation more probable, effective, long lasting and apt to spread' (Manzini, 2014, p. 65). Social innovation can follow a top-down, bottom-up as well as a hybrid approach in which a group of actors develop, experience and evaluate new solutions. As a result, the social innovation process becomes a highly dynamic, non-linear, process in which the roles of the designer can include the role of mediator (between different interests), facilitator (of other participant's ideas and initiatives) and co-developer (to conceive and realize design initiatives). The process itself requires co-design activities such as prototypes, mock-ups, design games, models, sketches and other materials (Manzini, 2014). A well-known examples of a social innovation is the Slow Food network.

Two main approaches can be distinguished, namely the user-centred and the participatory design process. The user centred design process considers the users as the source of innovation. Firms can derive clues to develop innovations by asking or observing the user needs (Dell'Era & Landoni, 2014). The participatory design process, instead, actively involves all relevant stakeholders (e.g., employees, partners, customers, citizens and end-users) at different stages of the innovation process from the initial exploration of the problem to conceiving and evaluating solutions (Dell'Era & Landoni, 2014). Literature has identified a wide range of tools which support the social innovation process such as interviews, focus groups, applied ethnography, lead-user innovation and beta-testing (Dell'Era & Landoni, 2014) as well as Living Labs and other co-creation methods (Grönroos, 2008; Payne et al., 2008; Prahalad and Ramaswamy, 2004). The degree of explicitly of the user-need attempted to understand has a major impact on which tool to select (Sanders, 2002).

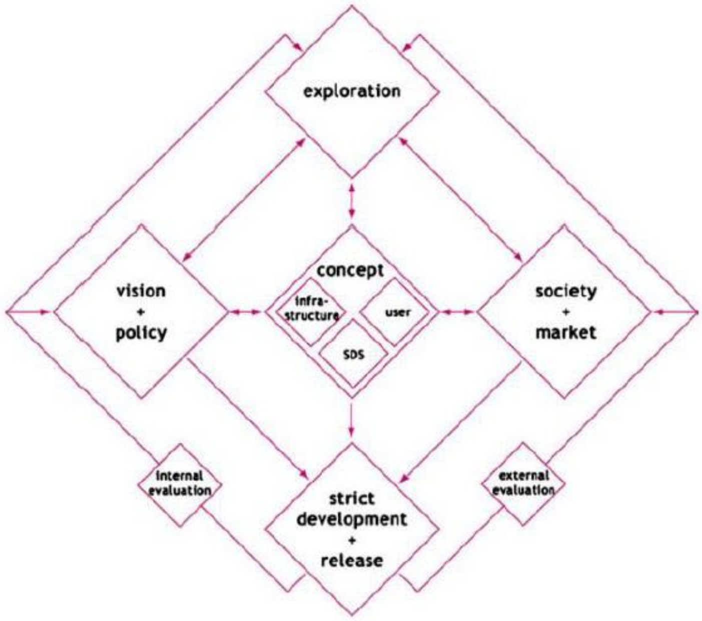
2.2.3. Sustainable business model innovation process

The sustainable business model innovation process by Geissdoerfer et al. (2017) resembles the design thinking process while taking into account the particularities of business model innovation. The process moves from concept design, to detailed design to implementation via nine steps namely, ideation, concept design, virtual prototyping, experimenting, detail design, piloting, launch, adjustment and diversification. The steps are iterative as lessons learnt in one step can lead to changes in previous steps. Moreover, multiple stakeholders of the firm are involved in each of the steps.

2.2.4. Sustainable innovation diamond

The sustainable innovation diamond by Hallenga-Brink and Brezet (2005) – depicted in Figure 2 – offers a promising complementary perspective. First, the sustainable innovation diamond approaches the sb-SOI process as natural as possible by allowing illogical sideways and feedback loops in a chaotic sense. This represents a commitment to a sb-SOI process without a clear beginning and end. Second, the innovation diamond explicitly involves “filter” moments where ideas are checked with boundary conditions such as external stakeholders and boundary conditions such as stakeholders, governments, local communities and businesses as well as with internal boundary conditions such as the management, vision and policies of the direct stakeholders. As a result, compared to the design thinking process, the defining, ideation and prototyping stages are flung open and allows to constantly check and develop the sb-SOI based upon stakeholder perspectives which might be previously unrecognized, murky and immeasurable, especially in the beginning.

Figure 2 – The sustainable innovation diamond – adopted from Hallenga-Brink and Brezet (2005)



2.3. Research aim

As evident from table 1, despite the innovation processes documented in the literature, an innovation process which takes into account all relevant aspects for sb-SOIs does not exist to the best of our knowledge. We, therefore, aim to create a better understanding of the innovation process for sb-SOIs.

Table 1 *– Innovation processes and their suitability for sb-SOIs*

<table>
<tr><th>Innovation process</th><th>Guiding the SOI from the trigger to the implementation</th><th>Collective involvement of multiple actors</th><th>Guidance on the three fits for adoption of new technologies</th><th>Fostering sustainability</th><th>Gap in literature</th></tr>
<tr><td>Design thinking</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td rowspan="4">Existing frameworks do not describe:

1) how to involve multiple actors

2) how to develop shared value propositions

3) how to integrate behavioural change</td></tr>
<tr><td>Social innovation process</td><td>Yes</td><td>Partly</td><td>No</td><td>Partly</td></tr>
<tr><td>Sustainable innovation diamond</td><td>Partly</td><td>Yes</td><td>No</td><td>Yes</td></tr>
<tr><td>Sustainable business model</td><td>Yes</td><td>Partly</td><td>No</td><td>Yes</td></tr>
</table>

innovation process					4) the innovation process from start to finish

3. Methodology

This research follows an action research approach in the pursuit of *what can be* (van Aken et al., 2016, p. 2) by adopting the principles of the design science approach (Holmström et al., 2009). Neither an inclusively deductive nor inductive logic sufficed to describe the problem (i.e. the peculiarities to take into account to develop system-building SOIs) and propose a solution (i.e. a system-building SOI process). Rather, we recognized the need to understand and reframe the problem of how to develop SOIs. Solving the newly framed problem required us to iterate from the empirical problem to theory and back in an abductive manner to arrive at the evidence and insights needed for the solution to the problem (Chandrasekaran et al., 2020).

The data collection and analysis followed the four phase iterative process as suggested by the design science approach (Holmström et al., 2009). First, the initially ill-structured problem situation on how to implement SOIs was analysed to define the problem and to incubate an initial proposal for the solution. Second, we extended and refined the solution through a combination of design improvements, implementation and evaluation with three sustainable innovation pilots (SIPs) (Holmström et al., 2009). In the third and fourth phase, we derived key explanations and the theoretical relevance from the developed solution. The next sections first describe the problem context and then describe the methodology behind the first two phases. The third and fourth phase form the discussion section of this paper.

3.1. Problem context: data-driven sb-SOIs in the agri-food industry

Although relatively few organizations or industries appear to adopt sb-SOIs (Adams et al., 2016), the agri-food industry is one of the few sectors in which sb-SOIs start to unfold. Global industrial pressure on agriculture to produce ever more food at ever lower costs has placed strains on the environmental, social and economic sustainability of agriculture. Roughly one third of the global anthropogenic GHG emissions come from the food system and, within the food system, farming processes contribute to approximately 71% of the GHG emissions (Crippa et al., 2021). Besides the environmental sustainability, farmers are expected to play a major role in tackling pressing social issues such as inclusion (fair trade) and ensuring access to healthy and nutritious food for a growing population (Béné et al., 2019). In fact, the adoption of the United Nation's Sustainable Development Goals (SDGs) in 2015 and the EU's Farm to Fork strategy signals a global commitment to combat the social, environmental and economic sustainability of the agricultural sector.

Although many responses exist to tackle the sustainable challenges of agriculture (e.g. reduced tillage, crop rotation, perennial farming, agroforestry and precision fertilizer/pesticide management – we refer to Rosenzweig et al. (2020) for an extensive overview), the uptake of those responses in practice remains limited. The limited uptake can, at least partly, be explained by the context of the agri-food value chain in which farmers operate. The agri-food value chain is composed of a complex network of interrelated actors which produce, process, distribute and consume food (Cagliano et al., 2016). The power within the agri-food chains reside within multinationals and downstream buyers who apply intense pressure on farmers to lower their prices. Globalization, liberalization and the commodity nature of many food products further augment the price pressure and leave farmers as price-takers with little bargaining power (Stanco et al., 2020). As such, farmers have little room to invest in sustainable practices.

Hence, without system-wide support, farmers have little opportunity to respond to the environmental and social pressures exerted on them – as such pointing towards the need for sb-SOIs. Although there is no clear path on how to implement system-building SOIs with multiple value chain actors, several developments such as the adoption of new data-driven innovations like sensors and precision farming are predicted to play a major role in sustainable farming (Stanco et al., 2020). We therefore developed and implemented the sb-SOI process at eight SIPs which are part of the Horizon2020 Ploutos project[1]– see table 2 for more details on each SIP.

***Table 2** – Overview of the SIPs*

Project code	**Country**	**Involved actors (bold: project leader)**	**Brief description of the challenge**
SIP 1	Greece	Farmers, processing industry, farmer's union, **technology provider**, government, research partner, government	Supporting a frozen fruit value chain with small farmers, to optimize production, reduce environmental footprint and re-use data for certification and subsidies
SIP 2	Ireland	Farmers, farmer's association, **regional community organization**, technology provider, research partner	Smart farming on rural farms demonstrating its benefits in the wider agri-food community and co-creating new food products and services

[1] The Horizon2020 Ploutos project is a European funded project (GA 101000594) aimed at implementing SOIs in the agri-food value chain. For more information, see https://ploutos-h2020.eu/.

SIP 3	Italy	Farmers, **technology provider**, farmer's association, research partner	Increase sustainability in the grapevine sector by introducing payments for ecosystem services provision and parametric insurance to support losses from sustainable approaches
SIP4	Spain	Farmers, agri-food cooperation, distribution, **technology provider**, tourism office, regional government	Improving the sustainability of Balearic agri-food chains with Smart Farming and by using the collected info to organize agri-food tourism
SIP5	Serbia, North Macedonia	Farmers, **platform operator**, technology provider (2x)	Facilitating the transfer of surplus food from farmers to socially disadvantaged groups, by aligning logistics and processes
SIP6	The Netherlands	Farmers, **organic branch organization**, trader, technology partner	Carbon farming: compensating farmers for climate friendly soil management
SIP7	Cyprus	Wineries, export partner, **local government**	Supporting wine producers to take advantage of the changes in labelling regulations and enhancing their sustainability performance
SIP8	France, Greece, United Kingdom, Germany, Belgium	Farmers, **farmer's representative**, technology provider	Empowering customers through crowdsourcing to take back control over their food and create healthy, sustainable, fair-trade products

3.2. Phase 1: Solution incubation

Solution incubation consists of framing the problem, defining the objectives for the solution and developing the rudiments of a *potential* solution (Holmström et al., 2009). We deductively developed initial insights into elements of the potential solution by combining different literature streams (see result section). However, literature on SOIs in a multi-actor (agri-food) value chain is relatively scarce. Experts, who have accumulated vast experience through implementing SOIs in the agri-food sector, can provide knowledge on complex and interdisciplinary issues (Akkermans et al., 2003; Meredith et al., 1989). It seems therefore sensible to incubate the initial solution through listening to experts. In fact, other researchers in similar fields also relied on expert knowledge to develop solutions or processes to develop solutions, see for instance Geissdoerfer et al. (2016, 2017), Reefke and Sundaram (2017), Sauer and Seuring (2019) and Seuring and Müller (2008).

Although the literature does not provide a specific formula to determine the ideal number and the type of experts to involve in an expert study, some guidance can be gleaned from previous studies such as the studies from Akkermans et al. (2003) and Kembro et al. (2017). First, any given problem can be framed in different ways, depending on the point of view of the idiosyncratic background expertise of the researchers. To avoid subjectivity, we brought together experts from the three different disciplines – behaviour innovation, collective value propositions (and wider collaborative business modelling) and data-driven solutions – as well as stakeholders directly involved in the SIPs to reach consensus on the problem and the initial solution design. Second, the literature tends to agree that the total group size should be between 20 and 30 experts. A higher number of experts is unlikely to generate additional insights while a lower number of experts imposes the risk of biases related to individual opinions which can distort the aggregated response. Third, sub-groups of experts which represent different point of view should consist of 10 to 18 experts (Okoli and Pawlowski, 2004). For the solution incubation, we involved two subgroups. The first subgroup is composed of insider experts, namely the people working directly in the agri-food value chain (e.g., farmers, food processors and agri-tech providers). The second group is composed of outsider experts, namely experts from universities, research institutions, governments and NGOs. We relied upon the network of the Horizon2020 Ploutos project to invite the insider and outsider experts. As shown in Table 3, the experts represent various European countries and have a rich variety of backgrounds.

Table 3 *– Experts involved in the solution incubation*

Subgroup (# of experts)	**Type (# of experts)**	**Country**	**Organizations**	**Experts**
Insider experts (21)	Agri-tech provider (10)	Greece	2	4
		Spain	2	4
		Italy	1	2
		Slovenia	1	1
	Farmers and farmers' representatives (6)	Cyprus	1	2
		France	1	1
		Greece	1	1
		Ireland	1	1
		The Netherlands	1	1
	Agri-food advisory services (5)	Serbia	1	3
		The Netherlands	1	2
Outsider experts (14)	Universities (7)	Greece	1	2
		Italy	2	3
		United Kingdom	1	2
	Research institutes (3)	The Netherlands	1	3
	Government organizations (4)	Ireland	1	2
		Cyprus	1	2
Total			**20**	**35**

The objective of the expert studies is to revisit the problem and the rudimental solution, set objectives and develop an initial solution based on group consensus. To do so, we organized multiple rounds in which experts could share their view. The output from a round served as input for the next round of collecting views. New rounds were organized until we reached theoretical saturation – i.e., the point at which no new insights of the problem, the objectives and the rudimental solution emerge. Using multiple rounds to collect and aggregate input allowed the experts to comment and reflect on their own and on each other's views, as such increasing the construct validity of the solution incubation.

The rounds were organized through an online meeting platform with multiple experts connected at once. To avoid opinion leadership, for example caused by interpersonal biases, strong personalities, defensive attitudes and unproductive disagreements (Linstone and Turoff, 1975), we used anonymous tools such as online interactive whiteboards and online forms to collect the views of the experts during the online meetings and to enable experts to consider feedback from other experts and to change their views without the risk of embarrassment (Kembro et al., 2017).

Table 4 provides an overview of each of the rounds. Note, not all experts participated in every single round as larger group size might generate few additional insights while limiting experts to speak freely.

Table 4 *– Study design of the individual rounds*

Round	**Expert type (# of experts)**	**Defining the problem, the objective and the key elements of the rudimental solution**	**Developing the rudimental solution**	**Evaluation of the rudimental solution**
1	Outsider (6) Insider (5)	Identifying and operationalizing elements of collaborative sustainable business models, data-driven solutions and behavioural change in the context of SOIs in the agri-food sector.	Identifying the interrelations between the elements and the steps, nature and sequence of the rudimental solution in the context of SOIs in the agri-food sector.	-
2	Outsider (6) Insider (4)	Validation of the elements.	Validation of the rudimental solution based on the comments in round 1.	-
3	Outsider (3) Insider (1)	-	Validation of the rudimental solution based on the comments in round 2.	Evaluation by outsider experts.
4	Outsider (10)	-	-	Evaluation and

	Insider (16)			validation by outsider and insider experts.

3.3. Phase 2: Solution refinement

During the solution refinement phase, the rudimental solution is subjected to empirical testing. The design and field testing of the proposed process was carried out in a 14-month longitudinal process with eight SIPs. The SIPs implemented the rudimentary solution developed in phase 1. The authors, together with the experts, provided process consulting to the eight SIPs. We systematically collected and analysed feedback to evaluate the actions. Feedback was recorded, transcribed verbatim and coded to search for explanations and improvements of the solution.

4. Findings

We present the findings in two sections in accordance to the first two phases of the design science approach.

4.1. Development of the rudimental solution for the sb-SOI process

The expert study identified several requirements for an effective sb-SOI process, namely:

- The sb-SOI process should combine “Industry 4.0” technologies, collaborative business models and behavioural change into a single integrated solution.
- Measuring sustainable performance is important both at the beginning of the sb-SOI process to understand the problem as well as at the end of the sb-SOI process process to evaluate the final outcome.
- During the development of the solution for the sb-SOI process, sustainability should explicitly be taken into account.
- The sb-SOI process should involve and consider the interests of multiple stakeholders to ensure an orchestrated effort by all stakeholders rather than focusing on isolated interests of single actors to develop a feasible, desirable and viable sb-SOI for all actors.

Furthermore, the experts indicated that the design thinking process developed by Plattner et al. (2010) is a promising avenue. However, the experts also acknowledged the shortcomings of design thinking as identified by Iskander (2018). In particular, the experts recognized the need to integrate chaotic, complex and non-linear co-creation processes with all stakeholders prominently into the sb-SOI process. With regards to this, the design diamond by Hallenga-Brink and Brezet (2005) offers a promising complementary perspective. As a result, the defining, ideation and prototyping stages of the design thinking process are flung open to constantly check and develop the sb-SOI based upon stakeholder perspectives which might otherwise be unrecognized, murky and immeasurable.

The process developed by the experts can be summarized as:

1. Understand the problem from sustainability point of view.
2. Define the goal.
3. Ideate the solution by imagining solutions based on behavioural change, shared value proposition and from the additional elements of the potential solution. Constantly reflect on the ideated solution and the defined goal and the interests of all stakeholders. If needed, re-iterate back to step 1.
4. Experiment with the best ideated solution and check the solution against the defined goal and the interests of all stakeholders. If needed, re-iterate back to step 1 or 3.
5. Evaluate the final solution in depth from a sustainable point of view. If needed, re-iterate back to step 1 or 3.
6. Implement the final solution.

4.2. Refinement of the rudimental solution for the sb-SOI process

During the implementation of the sb-SOI process at the eight SIPs, several challenges emerged. First, in SIP1, it remained unclear what the customers, retailers and food processors valued in terms of shared information in the traceability system (e.g. type and amount of fertilizers, pesticides and water use). Moreover, retailers may by-pass non mandatory traceability systems and opt for cheaper, but non traceable, products. Finally, the farmers in SIP1 where reluctant to share the data. Similar challenges were found in the other SIPs. In addition, in SIP2, the farmers experienced difficulties in working with the interface of data-driven solutions. These findings pointed out the need to understand and define the problem from the three angles of the envisioned solution: the shared value proposition, the behaviour change and the data-driven innovations. Tools and exercises such as the customer journey, stakeholder analysis, PESTEL (shared value proposition), exploring the dynamics of the eco-system, identifying shared values (behaviour change), user stories and an assessment of available existing technologies (data-driven solution) proved useful to create a deep understanding and to define the problem.

Second, with regards to the sustainable outcome of the innovation, we found that as 1) the sustainable objectives were clearly set at the beginning of the sb-SOI process and 2) the elements of the sb-SOI were sustainable by design (e.g. precision farming) the proposed sb-SOIs were sustainable. Although ideally a thorough assessment would be made to evaluate alternative sb-SOIs, for example by performing a Life Cycle Assessment, such time is often not available in an innovation process. We therefore relied on expert opinions for comparing different sb-SOIs in order to progress more quickly.

Based on the above, the sb-SOI process was refined as follows, where changes to the initial design are highlighted using italics:

1. Understand the problem from sustainability point of view *as well as from a behavioural and shared value proposition point of view and identify additional elements of the potential solution (e.g. "Industry 4.0" solutions) together will all actors using different analysis tools.*
2. Define the goal.
3. Ideate the solution by imagining solutions based on behavioural change, shared value proposition and from the additional elements of the potential solution. Constantly reflect on the ideated solution and the defined goal and the interests of all stakeholders. If needed, re-iterate back to step 1.
4. Discuss the sustainability of potential sb-SOIs with experts to get a quick perspective on the sustainability of each ideated solution.
5. Experiment with the best ideated solution and check the solution against the defined goal and the interests of all stakeholders. If needed, re-iterate back to step 1 or 3.
6. Evaluate the final solution in depth from a sustainable point of view. If needed, re-iterate back to step 1 or 3.
7. Implement the final solution.

5. Discussion and conclusion

From a practical point of view, the developed sb-SOI process can guide practitioners in developing sb-SOIs. From a theoretical point of view, several insights can be gleaned from our study. First, to the best of our knowledge, the developed sb-SOI process is the first process which involves multiple actors to develop a sb-SOI with a shared value proposition.

As such, we expand the body of literature on innovation processes. Second, our research provides insights into the role of value chain actors in achieving sb-SOIs.

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