Sustainability-Oriented Innovation for System-Level Impact

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ABSTRACT

The promise of sustainability-oriented innovation (SOI) as a way for firms to positively impact complex, systemic social and environmental challenges is widely embraced but little is known about the system-level impact of SOI. Although previous research suggests that working with stakeholders can enhance such innovation, the escalation of sustainability challenges indicates that we do not yet fully understand how to achieve system-level impact. To address this situation, we develop a framework to operationalize the system-level impact of SOI. We then apply qualitative comparative analysis (QCA) to empirically study different configurations of stakeholder involvement in SOI from 14 firms in eight countries in relation to their system-level impact. We find two distinct recipes for achieving such impact through SOI indicating that firms can choose a radically open collaboration with many non-profit oriented stakeholders or a more targeted approach to collaboration that includes a greater proportion of for-profit partners coupled with a specific impact extender. The equifinality we discover has implications for firm-level decision-making in terms of the type of stakeholders selected and the timing of their involvement. Our results bring systems thinking closer to firm-level action. We additionally identify a role for governmental stakeholders contributing to the renewed interest in management studies around government activities in innovation for complex sustainability challenges.

Keywords:

sustainability-oriented innovation; system-level impact; configurational; stakeholders; collaboration; grand challenges

The need for innovation in business to advance systemic solutions to complex challenges such as climate change, biodiversity loss or entrenched social inequalities has been widely extolled (Eisenhardt, Graebner, & Sonenshein, 2016; Khavul & Bruton, 2013; Wasieleski, Waddock, Fort, & Guimarães-Costa, 2021). But despite the promise of sustainability-oriented innovation (SOI), that is new product, service or business model solutions which reduce ecological/social harm and create ecological/social benefits, sustainability challenges continue to escalate. Recent summer months have produced the warmest global air and sea temperatures ever recorded (The Copernicus Climate Change Service, 2023). Over 100 wildfires raged around Europe emitting an estimated 20 million tons of carbon dioxide (EU, 2023), while in Canada 13.5 million hectares were burned, almost double that of previous years (NASA, 2023). Biodiversity loss continues to advance: a million plants and animals are threatened by extinction (Almond, Grooten, Bignoli, & Petersen, T., 2022). In our societies, migration rose rapidly during the early 2020s with over 122 million individuals forcibly displaced globally by the end of June 2024 (UNHCR, 2024).

Such grand challenges are now frequently identified in the management literature as a key concern for firms (Bansal et al., 2021; Howard-Grenville, 2021), prompting calls for innovative responses which can contribute to the wider system transformations necessary to resolve them. Others rightly caution that individual firms innovating alone are unlikely to bring about a full system change or solve complex challenges (Kuhlmann & Rip, 2018; Williams, Perego, & Whiteman, 2024). We find that these two seemingly contradictory claims are simultaneously true: one firm's innovation is unlikely to change a system (Loorbach et al., 2020), but it can have an *impact* on the system(s) in which it is nested (Bansal et al., 2021; Howard-Grenville, 2021). Previous literature however does not provide clear ways for assessing the impact of a firm's innovation on the system-level while more broadly in the management literature there is limited

empirical work on how firms are embedded in surrounding social and environmental sustainability systems (Williams et al., 2024). Seeking to discover ways to connect firm action like innovation with wider impact, we develop – to the best of our knowledge – the first framework to operationalize the system-level impact of sustainability-oriented innovation (SOI).

Another important question concerns the type of stakeholder collaboration in SOI to achieve system-level impact. Some suggest that when innovating toward sustainability, organizations should include diverse knowledge bases, expertise and perspectives of stakeholders to have a wider system-level impact which goes beyond the commercial and/or narrow benefit of a few (Adams, Jeanrenaud, Bessant, David Denyer, & Overy, 2016; Bansal et al., 2021; Voegtlin, Scherer, Stahl, & Hawn, 2022). This would require firms to collaborate with stakeholders offering such diversity and raises important questions around whom to involve in the firm's core processes like innovation and at what point in the innovation process stakeholders can nurture wider impact of SOI. In light of this we ask: *What kind of firm-stakeholder collaboration in SOI is associated with system-level impact?*

Very few things in the world, be they happy marriages or system-level impact of SOI, are the result of a single recipe. A rigorous exploration of multiple recipes can illuminate various feasible options to achieve much needed system-level impact. To address such equifinality, we apply qualitative comparative analysis (QCA), which enables scrutiny of multiple configurations (Crilly, Zollo, & Hansen, 2012; Fiss, 2007; Misangyi et al., 2017) associated with innovations which have an impact at the system level, and explore this with qualitative data collected from 14 firms across eight countries in Europe as they undertook SOI within domains highly pertinent to sustainability.

We introduce a new, previously neglected categorization for studying the stakeholder groups integrated in SOI processes, that of stakeholder profit-orientation, and bring fresh empirical evidence to inconclusive findings around the timing of stakeholder interventions. These new inputs - a system-level impact framework, a categorization of stakeholders by profit-orientation and a greater scrutiny of stakeholder interventions - help us to identify two different configurations or "recipes" of stakeholder integration which can be associated with system-level impact of a sustainability-oriented innovation. These recipes contrast collaboration with many non-profit-oriented stakeholders at the early phases of the innovation process versus cooperating with a single stakeholder that extends the impact of the innovation beyond its original scope. The equifinality results contribute to the emerging literature on socio-ecological systems in management studies. Furthermore, we reveal the presence of governmental stakeholders in innovations that are associated with system-level impact, suggesting the role of government deserves more scrutiny in management studies and political science research addressing innovation for complex sustainability challenges.

The body of the paper is organized as follows. We first consider insights from the systems perspective, the potential for SOI to have an impact on various aspects of systems, and stakeholder integration into SOI in relation to such impact, which provide the backdrop for our study. In the method section we introduce the empirical setting, develop the outcome and conditions selected for the analysis and explain how we apply the QCA methodology. The subsequent sections present our findings which are then discussed in terms of their implications for both research and practice.

INSIGHTS FROM THE LITERATURE

Research on complex challenges in management studies has begun to take a systems approach, especially in the theoretical sphere (Dentoni et al., 2021; Tashman, 2021; Bansal et al.,

2021; Whiteman et al., 2013; Williams et al., 2021). It has also been frequently suggested that innovation is needed to combat the eroding sustainability of complex, interdependent and multi-directional human and natural systems (Howard-Grenville, 2021; Williams et al., 2024), systems which intertwine ecological, social, political, economic and technological facets (Biggs et al., 2021; Chapin et al., 2009; Starik and Rands, 1995; Tashman, 2021). This is appealing and powerful, but the management literature is missing an empirical understanding of how firms are embedded in the social and ecological systems around them (Williams et al., 2024). At least two key items are needed to move this line of inquiry forward. Firstly, ways of assessing the system-level impact of firms' innovations, and secondly empirically grounded mid-range theorizing about sets of factors that advance system-level impact from innovations.

Sustainability-oriented innovation and system-level impact

Management literature has been vocal about the importance of SOI to stimulate systems change (Eisenhardt et al., 2016; Khavul & Bruton, 2013; Wasieleski et al., 2021) but struggles to connect the dots between firms' innovations and their impact on the systems in which they are nested. Adams et al., (2016) suggest that systems' building innovation reaches beyond the boundaries of the firm as a means of societal and institutional advancement towards sustainable development and that, in contrast, insular innovation has an impact predominantly at the firm or product level. The first research need lies with the lack of operationalizable frameworks or models that would facilitate an assessment of how a firm's SOI influences the system (or not). Analyzing systems change as a result of one firm's innovation is tricky, because full systems change is typically beyond the reach of a single innovation and may only be visible retrospectively over years or decades (Loorbach et. al., 2020). Here we want to take the first step of investigating what it takes for an innovation to have impact on a system level. To that end we next visit both

management literature and sustainability studies to bring to light what can be conceived as a system impact of an innovation (Biggs et al., 2021; Chapin et al., 2009; Dentoni et al., 2021).

Innovations with system-level impact would involve changes in the wider political system such as the emergence of new regulations or institutions governing resource flows (Biggs et al., 2021; de Medeiros et al., 2014; Olsson et al., 2017). They could also influence economic policy in relation to infrastructure development. For example, the resilience necessary for human activities could be built into infrastructure such as flood control and energy provision (Chapin et al., 2009; McMeekin, Geels, & Hodson, 2019).

Such innovations would create fundamental changes in knowledge and technological systems. New technology is necessary to achieve sustainable natural resource consumption (Tashman, 2021), and would need to be accompanied by significant shifts in knowledge, capabilities (Gatignon, Tushman, Smith, & Anderson, 2002) and inter-organizational processes that can reach across industries, potentially leading to wider alterations in the structure of markets (Geroski & Pomroy, 1990; Tischner, 2008). For example, as technology enables the development of energy storage, electrification of personal transportation significantly alters the market by having impacts on the vehicles themselves and stimulating the provision of charging and other related services and infrastructure. However single innovations or novelties alone are less likely to reach a system-level impact, requiring rather a combination of different ideas, concepts and technologies (Olsson et al., 2017) which combine products and services (Tukker, 2004).

Furthermore, innovations with system-level impact could induce consumer behavior change, for example a shift towards non-ownership usage by consumers. This can change the context of use and help to avoid adverse sustainability impacts such as a potential rebound effect from new technologies and efficiencies (Castro, Trevisan, Pigosso, & Mascarenhas, 2022; Lange,

Kern, Peuckert, & Santarius, 2021) and, critical for socio-ecological systems, avoid overconsumption which puts pressure on natural resources (Chapin et al., 2009; Tashman, 2021). Table 1 draws these theoretical components together into a framework that facilitates our empirical study, and facilitates future research by others.

INSERT TABLE 1 ABOUT HERE

The framework helps to assess the capacity of sustainability-oriented innovations, that is new products, services or business models which reduce ecological/social harm and create ecological/social benefits, to have a system-level impact. This can occur when an innovation results in a reconfiguration of processes, actors, networks and structures at multiple levels, thus reducing ecological/social harm and creating ecological/social benefits in the system in which it is nested (Voegtlin & Scherer, 2017; Williams, Kennedy, Philipp, & Whiteman, 2017).

Stakeholder collaboration in innovation

The next open question about the potential of SOIs for system-level impact is empirical and concerns the characteristics of SOI processes that are associated with such impact. Although these characteristics could naturally be manifold, we take stakeholder collaboration, the most distinctive precondition acknowledged in the literature as influential for system-level impact (Adams et al, 2016; Dentoni et al., 2021; Valente, 2010), as our "anchor" from which we complexify to include other connected characteristics identified in the following paragraphs (Furnari et al., 2021).

From a systems perspective, it has been suggested that interaction between different stakeholders "acts like a proxy for the appreciation of the interconnectedness of social, ecological,

political, and economic issues" (Valente, 2010), which would produce a "healthy tension" between different social, cultural and economic needs. This suggests that a greater diversity of perspectives would allow for different ideas and creativity not only in innovation (Biggs et al., 2021) but more widely exposing traditional actors to alternative worldviews and insights into how their behavior connects to the bigger system (Valente, 2010). Similarly, previous research suggests the need for including multiple and diverse stakeholders with different mindsets and competencies in SOI (Ayuso, Rodríguez, García-Castro, & Ariño, 2011; Slotegraaf, 2012), particularly if radical and system-level impacts are targeted (Adams et al., 2016; Inigo, Albareda, & Ritala, 2017; Inigo, Ritala, & Albareda, 2020). However, while pointing to the relative importance of partners with differing viewpoints, previous empirical research is sparse and is not entirely conclusive.

Previous studies have explored the role of stakeholders in SOI. Indeed, business sector partners as well as NGOs, academic research institutions, (local, regional, national) government organizations, and social enterprises are all found to participate in SOI processes of firms (Juntunen et al., 2019). Typical categorizations used to study stakeholders are primary and secondary stakeholders (Ayuso et al., 2011; Hall & Martin, 2005), fringe stakeholders (Hart & Sharma, 2004) or market and non-market stakeholders (Driessen & Hillebrand, 2013). In addition to distinct profit-oriented and non-profit-oriented organizations, there are hybrid organizations with a propensity to advance social innovation (Haigh et al., 2015; Hockerts, 2015; Hoffman et al., 2010). Previous literature on cross-sector collaboration indicates that stakeholder profit-orientation is a potentially relevant criteria (Ber & Branzei, 2010; Dentoni et al., 2021; Santos, 2012), but it has been so far neglected in empirical systems impact research. In a context where organizations seek to collaborate for systems impact, stakeholder profit-orientation merits further attention.

Aside from profit orientation, innovation literature suggests "intermediary" stakeholders (Bakici et al., 2013; Howells, 2006) play a wide variety of roles in SOI processes ranging from systems roles such as regulator, advocate or decision-maker to organizational roles like initiator, broker/mediator or context enabler (Howells, 2006; Lyon et al., 2020). Proactive roles such as an impact extender where a stakeholder promotes the use of the product or service beyond its original sphere, and/or extends the impact of the innovation into other social or environmental aspects of sustainability (Goodman et al., 2017; Inigo et al., 2020; Lyon et al., 2020) open a promising line of inquiry in relation to system-level impact. In the context of sustainability transitions, government and local authorities have been found to help raise awareness and create legitimacy, while other types of intermediaries are more able to articulate societal needs for change (Kivimaa et al., 2019). Recent research argues that new roles for government in business sustainability are emerging and recommends management scholarship scrutinize their function and dynamics (Kourula et al., 2019). Some of these roles involve forms of collaboration, but scholarship "reintroducing government" into management studies is yet to explore the ways and outcomes of participation of government stakeholders in business' sustainability innovation (George et al. 2024; Wickert, 2021).

The timing of stakeholders' interventions and activities also matters (Voegtlin et al., 2022) although findings are inconclusive. While collaboration with stakeholders early in the innovation process can be seen as advantageous given that most environmental impacts are determined in the product-planning phase (Bocken et al., 2014; Hoffmann, 2012; Phillips et al., 2019), others have claimed that stakeholders can play different roles in sustainability-oriented innovations at early and late stages of the process (Purtik & Arenas, 2019). Our framework for assessing system-level

impact, coupled with our explorations using a methodology that can surface different ways of achieving the same end, are designed to shed new light on these important problems.

EMPIRICAL STUDY OF SUSTAINABILITY-ORIENTED INNOVATION

Sample and Data

Our unit of analysis is SOI processes that included collaboration with stakeholders. In order to determine the cases which met the theoretical relevance to the research question (Thomann & Maggetti, 2020), the point of departure in our purposeful sampling strategy with criterion-based case selection (Patton, 2015) was to find company cases which had developed SOIs with stakeholders. We searched from two publicly available lists, one focusing on listing top firms on creativity and inventiveness[1] and the other focusing to sustainability performance[2] and by asking for inputs from sustainability experts in academia, the corporate sector, and government agencies. Our initial list comprised 147 cases. The second case selection criterion was to include only medium or large[3] consumer facing firms in four key sustainability domains - energy, mobility, living and food - that had used a collaborative innovation process with the intention of contributing to social and/or environmental sustainability. We selected firms from different areas of Europe – Nordics and Central, Eastern and Southern Europe - drawing on the expertise of researchers knowledgeable about SOI in each area. Our final criterion was to select cases which allowed us to gain in-depth empirical knowledge on stakeholder integration. Following this criterion, we undertook extensive desk research and excluded firms which had merely organized idea competitions or crowdsourced ideas from stakeholders. Our final case selection included 14 firms across 8 countries in Europe (see Table 2) which undertook SOI processes in collaboration with

[1] Forbes rankings of the 100 most innovative companies
[2] Dow Jones Sustainability Index
[3] The categorization for company size is based on the European Union definition according to the number of employees: medium (50-249 employees) and large (250 employees and over)

stakeholders. Given the complex and connected nature of the explanatory factors, as yet unresolved in the existing literature on SOI outlined in the previous section, we employ qualitative comparative analysis (QCA) to study the interplay between the stakeholder network conditions and the timing of stakeholder collaboration, and how they are associated with the insular and system-level impact of SOI.

INSERT TABLE 2 ABOUT HERE

A total of 82 semi-structured interviews (averaging 60 minutes in length) were conducted with 34 company representatives and 48 stakeholders (average of approximately 6 interviewees per case) by a researcher familiar with the research project and geographical context. Interviews were transcribed and, if necessary, translated into English and held in a database accessible to the authors. Firm representatives and stakeholders were selected for their close knowledge of, or collaboration in the innovation processes and contacted by the researchers. A snowballing approach was taken to identify the individuals most familiar with the SOI process. Standardized case reports of 30-50 pages were developed for each innovation process according to an agreed reporting structure. These reports were based on the interview transcripts as well as extensive desk research including press releases, news and blogs linked to the firm and the specific innovation offering a rich initial dataset. Coding of all the case reports was undertaken manually by one of the authors using NVivo 10 and codes were regularly discussed during the analysis among all three authors allowing a deep understanding of all the cases and contexts. The codes identified the different stages of the innovation process (idea generation, product development, commercialization, and post-launch), the different types of stakeholders who collaborated in the

focal SOI, their activities and the timing of their interventions in the innovation process with the firm (see Table 3 for details of the innovation process, sustainability orientation of the innovation and the stakeholders involved).

INSERT TABLE 3 ABOUT HERE

Configurational approach to SOI

For the analysis of stakeholder collaboration, antecedents to the system-level impact of innovation are unlikely to operate in isolation but rather in an interdependent manner (Schneider & Wagemann, 2012). Certain combinations of these antecedents are likely to be meaningful in determining the system-level impact of SOI (Aguinis & Glavas, 2012; Margolis & Walsh, 2003) and no single cause may be either necessary or sufficient to determine the outcome of system-level impact. This is called conjunctural causation. A configurational approach, and QCA method, can examine the relationships between and among antecedent conditions and characterizes cases as having a particular combination of conditions associated with the outcome.

In addition to conjunctural causation, QCA has other advantages over correlation-based methods which are equifinality, and causal asymmetry. QCA methods can reveal several recipes associated with the outcome (see Crilly et al., 2012) which has generally been labeled equifinality. In the context of this study multiple different stakeholder collaboration combinations can be associated with system-level impacts (Fiss, 2007; Rihoux & Ragin, 2008: 8–9). In QCA, the presence of a condition set and its negation denote two qualitatively different phenomena. Thus if a certain condition is relevant for the outcome, its absence is not necessarily associated with the absence of the outcome (Schneider & Wagemann, 2012: 322).

We took a traditional case-oriented approach in QCA using deep contextual knowledge throughout the analysis (Thomann & Maggetti, 2020) and analyzed the set of configurations associated with the outcome, system-level impact of SOI, with the help of fuzzy set QCA (fsQCA).

Outcome: System level impact

The focal outcome of our empirical study is the system-level impact of the innovation. We developed the set of components to measure the system-level outcome of SOI by drawing from socio-ecological systems and sustainable innovation literature as previously seen in Table 1. This set comprises eight components for tracking the result of the innovation process: (1) fundamental shifts in knowledge, (2) new combination of products and services, (3) reconfiguration of infrastructural elements, (4) changes in inter-organizational processes and structures, (5) changes in institutional policy and context, (6) altered market structure, (7) reconfiguration of actors and network and finally (8) changed context of use. We take the position that each of the components given above may have an impact on the surrounding systems and could therefore be applied to any type of innovation. However, for this study, our cases were selected because they were sustainability-oriented innovations (see Appendix 1 for a case example of JCDecaux) even though there was substantial variance at the level of impact on systems. We sum the components we identify in the cases to give a score from 0-8 in order to establish a measurement for system-level impact.

INSERT FIGURE 1 ABOUT HERE

Conditions

Insights from the literature regarding stakeholder participation in innovation lead us to focus on three conditions that seem likely to play important roles in the outcome of system-level impact of SOI, but in unknown ways (Figure 1). These conditions explore the profit orientation of the network of collaborating stakeholder organizations, the specific activities of the stakeholder during the innovation process and finally the timing of stakeholder integration in the innovation process. To understand the complexity of the collaboration we ask what configurations of firm-stakeholder collaboration in SOI are associated with impacts on the system beyond the firm or its product and/or service.

Stakeholder network profit orientation. A range of stakeholders have been found to be integrated into SOI (Ayuso et al., 2011; Driessen & Hillebrand, 2013; Inigo et al., 2020; Juntunen et al., 2019; Slotegraaf, 2012). While research in management studies has identified profit orientation as being a potentially relevant categorization for stakeholder collaboration in SOI (Dentoni et al., 2021; Vassallo et al., 2019), its potential has not yet been scrutinized empirically in SOI studies. Therefore, we differentiate between stakeholders with profit, non-profit or hybrid profit orientations in our research design as part of exploring the stakeholder collaboration aspect of SOI. The non-profit-oriented category covers a range of non-profit seeking stakeholders including civil society organizations and government stakeholders.

Stakeholder orientation was scored by assigning "-1" for for-profit stakeholders, "+1" for non-profit stakeholders and "0" for hybrid organizations. We then identified the stakeholder network profit orientation by calculating the mean of the stakeholder orientation score for each case. Against that backdrop and following the advice of Basurto & Speer (2012) on inductive development of a cut-off point which is sensible for the given context, in our QCA model we

measure how heavily dominated the network is by non-profit-oriented stakeholders. This is because the SOI cases under study here include so many non-profit-oriented stakeholders (see Table 3), that merely distinguishing between the majority of for- versus non-profit stakeholder networks would not have made sense. Consequently, our measure reflects the *extent* of collaboration with non-profit-oriented organizations rather than a simple majority.

Presence of impact extender. The different roles that stakeholders can play in SOI has been explored in several studies (Howells, 2006; Lyon et al., 2020). Recent findings suggest that a proactive impact extender role, defined as stakeholders who take the initiative to promote increased use of a sustainability-oriented product or service and undertake activities to extend impacts to other areas of sustainability that were not originally considered by the firm, is pertinent to innovation addressing social or environmental issues (Goodman et al., 2017; Inigo et al., 2020; Lyon et al., 2020), but the universality of this role is not really clear. We include the presence of an impact extender role in the innovation process as a second condition in our analysis.

Collaboration timing. Collaboration with stakeholders in the early stages of the process and the integration of environmental issues is often suggested to be beneficial (Voegtlin et al., 2022) as most environmental impacts are determined in the product-planning phase (Bocken et al., 2014; Hoffmann, 2012; Phillips et al., 2019). However, the latest research suggests that timing in stakeholder collaboration is highly contextual (Juntunen et al., 2019) and not well understood. To explore the issue of timing we distinguish between collaboration early on at the idea generation stage, and collaboration which happens later in the innovation process. We measure this with the presence or absence of idea generation with stakeholders.

Calibration of outcome and conditions

The QCA method is based on set theory and uses Boolean algebra. This means that in the calibration phase the category measures of outcome and conditions are being converted and categorized to 0 or 1 (crisp-set calibration) or a scale from 0 to 1 (multi-value QCA and fsQCA). Table 4 shows the calibration of the outcome and conditions.

INSERT TABLE 4 ABOUT HERE

Data-based case knowledge and theoretical knowledge should be used to make judgments when calibrating measures into set membership scores (Ragin, 2000: 309). A data-based approach uses the dataset at hand to define qualitative data-based anchor points which are built on semantic differences to determine set membership (Jopke & Gerrits, 2019; Legewie, 2017). Theory-based anchor points in turn build on existing theory or draw from the causal logic from previous findings (Basurto & Speer, 2012; Misangyi et al., 2017).

Calibration of outcome. After developing the components of the system-level impact of SOI we needed to calibrate the outcome. We used the direct method for calibration (Ragin, 2008), for which the most central decision is to decide the crossover point, in this case, how many of the components would be needed to consider the evidence for system-level impact of an SOI sufficiently solid. In such situations, methodology literature suggests establishing characteristics delineating the membership score in its archetypical form and, on the other hand, the minimum score or the "border criteria" for inclusion in the set (Legewie, 2017). In our sample, JCDecaux can be considered an archetypical case of reaching system-level impact, because it received the highest innovation outcome score of 8 where all the measured components were changed. Border criteria refer to the minimum characteristics (here the score of SOI's system-level impact

components) the case needs to be included in the set. In defining border criteria, we carefully considered our outcome model and case knowledge. On that basis we interpreted that four or more system-level impact components are needed for the innovation to be considered as having a system-level impact, otherwise it was considered insular. In our sample, BMW, HSL, JCDecaux, Skanska and Verbund had a system-level impact. Figure 2 presents a summary of all 14 cases and their outcome score. Next, we explain how our three conditions are measured.

INSERT FIGURE 2 ABOUT HERE

Calibration of conditions. We use a continuous fuzzy-set score and direct calibration for measuring the profit orientation of the stakeholder network. For the other conditions we use crisp-set values (0 to indicate fully out and 1 to indicate fully in). As utilizable theoretical knowledge is insufficient for defining calibration crossover points and thresholds for the profit orientation of the stakeholder network condition (calculated as a mean score), we used case knowledge to define these values (seen earlier in Table 4). Table 5 presents the fully calibrated data set which is used for the QCA analysis.

INSERT TABLE 5 ABOUT HERE

Analysis

Analytical approach. After the calibration we constructed a truth table to identify combinations of causal conditions associated with the outcome. Appendix 2 presents the truth table which lists all logically possible combinations of conditions with our empirical data. We tested

first an analysis of necessity and then moved on to an analysis of sufficiency. These analyses were conducted using the QCA[4] (Dusa, 2018) and SetMethods[5] (Oana et al., 2020) package for R[6]. The necessity test in QCA reveals whether one or multiple of the conditions (so called supersets) are necessary, being present or absent, to generate an outcome. We selected high consistency, coverage and relevance of necessity thresholds in the subset/superset function to find single conditions or combinations of conditions that could form together a necessary condition for a system-level or insular outcome[7]. The function did not produce any solutions indicating there are no necessary conditions[8].

We applied enhanced standard analysis (ESA) (Schneider & Wagemann, 2013) to find out which configurations of conditions in the innovation process are sufficient to achieve system-level impact. In the sufficiency analysis it is important to understand that the set of the cases features a limited diversity and there can be empirically unobserved cases that lead to a certain outcome which are not included in our sample. In our analysis we distinguished so called easy and difficult counterfactuals (Schneider & Wagemann, 2013) and used informed directional expectations based on existing research[9]. The purpose of making counterfactual assumptions (Schneider & Wagemann, 2012, p. 169) about unobserved cases is to recognize which are the core and peripheral causal conditions in terms of each solution. The use of ESA enables us to deal with empirically unobserved cases in such a way that we can ensure that the coding of the outcome in the truth table

[4] QCA version 3.22
[5] SetMethods version 4.0
[6] R version 4.3.3
[7] We used consistency (0.9), coverage (0.6), and RoN (0.5) thresholds.
[8] Necessity analysis, also called superset analysis, aims to find which conditions are necessary for the outcome. When no single condition is found, it is possible that there is a disjunction of conditions which is necessary for the outcome. To test for such a disjunction, we searched for supersets with high enough consistency (0.9) and coverage thresholds (0.6) following Thomann & Wittwer (2017: 37), but found no such supersets.
[9] Based on earlier literature (Bocken, Farracho, Bosworth, & Kemp, 2014; Hoffmann, 2012) we made a directional assumption that Idea generation with stakeholder(s) is associated with the system-level impact of SOI. We did not make any directional assumptions for the other conditions.

does not contradict prior findings of necessity or sufficiency (Schneider & Wagemann, 2012: 198–211)[10].

Throughout the process we followed best QCA practice outlined by Greckhamer et al. (2018). For the analysis, we set frequency cut off[11] to 2. We used a consistency cut-off 0.71 for the system-level outcome. We reached a 0.82 solution consistency score which is high enough for finding sufficient causal conditions (Ragin, 2008, p. 52). The solution coverage was 0.62 which indicates that our configurational model captures well the complex causality of the underlying outcome of systemic change. For the insular outcome, we set consistency cut-off to 0.60 which resulted in 0.75 consistency and 0.65 coverage for the solution. We used the intermediate and parsimonious solution to differentiate core and peripheral conditions.

Robustness test. We also made several robustness checks to find out the sensitivity ranges of consistency and calibration thresholds (Oana & Schneider, 2021). We followed the robustness check protocol (Oana & Schneider, 2021) to understand the sensitivity of the calibration using the function rob.calibrange function of SetMethods. The function can find the upper and lower bounds within which the result configurations stay the same. The function was used for the *Network heavily dominated by non-profit-oriented stakeholders* condition which is calibrated using fuzzy sets. For the condition we found that calibration of cross-over can be changed to 0.49 without impact on configuration terms in the results. The fully out threshold can be changed to 0.5 and

[10] The intermediate solution, used alongside the parsimonious solution in the results, risks including illogical assumptions. To avoid this, a three-step Enhanced Standard Analysis (ESA) has been developed. The first step, which checks for contradictions with necessity, was needless as our analysis did not reveal necessary conditions. In the second step, we checked for contradictory counterfactuals to assure that the same directional assumptions used for the system-level outcome are not used for producing the insular outcome or vice versa. The third and final step concerns checking for combinations of conditions which would contradict common sense. This step does not pertain to our research design as all the combinations of conditions are possible.

[11] We were sensitive towards measurement errors and exceptional cases and we included only empirically relevant rows in the truth-table analysis (Thomann & Maggetti, 2020)

fully in threshold be modified to 0.65 without impact. Furthermore, we tested raw consistency ranges for both system-level and insular outcomes. The consistency cut-off of the system-level outcome can be altered (from 0.71) to 0.67 without changes in the obtained configuration in the results. For the insular outcome the (original 0.60) consistency cut-off can be altered between 0.54 and 0.62 which still keeps the results unchanged [12]. In summary, we confirm that both system-level and insular configurations obtained from the analysis are robust.

RESULTS

All our cases lead to sustainability innovation as it was the basis of case selection, but some of them cannot be associated with a system-level impact having rather more limited insular impacts. We found two distinct configurations associated with system-level impact of SOI, implying that these innovations can result from different types of collaboration with stakeholders. These configurations, called here S1 and S2, are differentiated by the types of stakeholders involved in collaboration and their activities. S1 is characterized by innovating with a network heavily dominated by non-profit-oriented stakeholders, involved already at the idea generation phase. Besides civil society organizations, our category of non-profit-oriented stakeholders also includes various types of government stakeholders ranging from local and regional to national government bodies. In contrast, the S2 configuration has a stakeholder network with relatively more profit-oriented stakeholders and makes use of a proactive impact extender stakeholder which is absent in the S1 configuration.

In addition to the SOI configurations associated with system-level impact, we found two configurations, I1 and I2, with more insular outcomes predominantly at the level of intra-firm

[12] Knowing the sizes of the ranges informs us about how much the results depend on the raw consistency cut-off choices made. For the system-level outcome, the results show moderate sensitivity to changes in the consistency cut-off. The results for the insular outcome are highly robust even if the consistency cut-off values are modified.

processes or the product. In contrast to the innovations with system-level impact, neither I1 nor I2 involved stakeholders at the early idea generation stage. Configurations associated with system-level and insular impact of SOI feature in Table 6. Present conditions are marked with filled circles while absent conditions are indicated with crossed circles. Empty cells are ambivalent conditions which are not part of the configuration associated with a certain outcome.

INSERT TABLE 6 ABOUT HERE

Stakeholder collaboration associated with system-level impact

Configuration S1. The essence of this configuration is joint idea generation with non-profits. In other words, the system-level impact is associated with the firm collaborating with a network heavily dominated by non-profit-oriented stakeholders and it also involves stakeholders in the idea generation phase of the innovation. This is further complemented by the absence of an impact extender stakeholder as a peripheral condition.

One of the cases that followed this type of configuration is BMW. The company collaborated with an extensive, high-majority non-profit-oriented network when developing electric cars with innovative sustainability features, and the infrastructures and services supporting electric mobility. On one hand, there were product-level sustainability impacts: Recycled or renewable raw materials were used instead of thermoplastics, and resource use was reduced throughout the manufacturing process: 50% less energy, 70% less water and 100% renewable energy. On the other hand, the SOI included system-level outcomes such as charging stations throughout Germany, and new mobility service business models like ParkNow for finding a parking space, thus reducing mileage and emissions, and DriveNow for car-sharing, as well as

offering buyers of small e-cars the option to rent larger cars for instances when multiple passengers need to be accommodated.

The process involved extensive collaboration with stakeholders at an early stage and was stimulated at the outset by significant financial support from the German government to conduct research into electric vehicles. At the start of the project, BMW's cross-functional innovation team discussed with key mobility decision-makers including mayors and city planners, as well as sustainability-conscious consumers and members of the urban population in 20 cities worldwide. This was followed by an idea contest held in its Co-creation Lab on future mobility services. After developing the ideas from the community, BMW went on to hold internal workshops with experts from universities to consider the most noteworthy ideas. Due to the ambitious and forward-thinking nature of the innovation, one of the key challenges for BMW was to envisage future mobility needs, so it engaged early with stakeholders to explore and initiate the development process and involved them in trialing and experimenting with the product and associated services. Local government also proved essential for assuring various parking permits and shipping regulation for the electric vehicles.

The innovation from HSL to introduce a demand-responsive mini-bus transportation service followed the same recipe of collaborating with a high-majority non-profit-oriented network from the outset of the innovation. Reducing emissions and increasing inclusivity through improving comfort for groups such as children, the elderly and the disabled were key aims of the project. City government played an important role in stimulating the original idea through an innovation competition which also provided funding for developing the innovation. Other non-profit-oriented stakeholders – a university as technology developer, the traffic authority and

Government Innovation Fund – were essential for developing the service, particularly by participating in its development and trial stages.

Configuration S2. In contrast to S1, to achieve system-level impact, case companies in this configuration included an impact extender among their collaboration partners as a core condition. Notably, while the presence of a network heavily dominated by non-profit-oriented stakeholders was a core condition in S1, the absence of such a network was a peripheral condition in S2. Early idea generation with stakeholders was present but only as a peripheral condition.

JCDecaux is one of the case companies which achieved system-level impact through SOI. JCDecaux's innovation project, Velib', resulted in a zero-carbon cycle share initiative for Paris. CitéGreen, a sustainability focused for-profit social enterprise, was an important partner and significantly extended impact by building and motivating the community of Velib' users through setting challenges and offering rewards. According to CitéGreen's CEO, they focused on "co-animating and co-communicating with all the local actors… this community management aspect wasn't really obvious at the beginning, but it became a huge incentive for the proposition" accelerating the adoption of the service and increasing use by around 30% annually. Impact was extended into other areas of sustainable lifestyles through offering reward points to Velib' users which could be used to buy sustainability themed products and services offered by local retailers.

This community orientation complemented JCDecaux's traditional business to business expertise. CitéGreen worked directly with JCDecaux, as the social enterprise's CEO explained "we chose very pragmatically this way of private contracting through operators … to get quicker access to the territory and to be able to launch more quickly".

Additionally, stakeholders such as the City of Paris, cycling associations and citizens played a role in this SOI. They helped with infrastructure challenges such as the conversion of

parking places and the development of an extensive cycle lane network as well as offering insights into road safety, transport habits and lifestyles helping to make Velib' as inclusive as possible.

A further example of such a system-level impact through SOI is Skanska's innovation, BoKlok, which resulted in affordable and ecological housing with vegetable garden access, proximity to public transportation and availability of communal spaces to reduce the need for large apartments. Ikea was the key partner for Skanska in BoKlok innovating from the idea generation phase onwards and Ikea's activities also extended the impact of the innovation. With its speciality in consumer knowledge, efficient designs, standardization, and cheapness, Ikea critically contributed to simultaneously attractive and affordable interior design of BoKlok. Later in the process it played an impact extender role promoting BoKlok as a lifestyle by recreating the BoKlok interiors within the Ikea store, by organizing a lottery of the first 36 BoKlok homes, by giving gift certificates, by promoting BoKlok through their register of hundreds of thousands of customers and chatter on social media. These activities extended awareness and raised widespread interest in the social and environmental impacts of Skanska's BoKlok concept which was relatively unknown among its target market. To cite Skanska's business development manager "Ikea was essential, because they understand the consumers' life and affordable prices, smart design. And they have some kind of lightness and happiness that we as a company are lacking. We are quite serious and kind of...construction company".

City planners were involved by helping to identify suitable locations and shifting the regulatory context to accommodate the project. This collaboration between construction companies and government which offered affordable housing, supporting sustainable mobility and urban gardening made Skanska's BoKlok a model example for further initiatives.

Both Skanska and JCDecaux examples show the importance of a for-profit partner with experience and skills in animating consumer markets to extend the impact of an SOI developed by typically business to business-oriented firms. Although non-profit oriented stakeholders did not dominate the network in S2 as they did in S1, city level government still played a role, albeit differently, in these cases.

Stakeholder collaboration associated with insular impact

Both configurations I1 and I2 are based on integrating stakeholders into SOI processes only after the idea generation stage (timing), but they differ in terms of the stakeholder network aspects.

Configuration I1. The first configuration associated with an insular impact outcome showed evidence of collaboration but did not rely on a high majority of non-profit-oriented stakeholders in the collaboration network. Furthermore, stakeholders were integrated only in the later phases of the innovation process.

The 'ready to assemble' home waste management kit of Ikea Poland was developed to help waste sorting in small kitchens of Polish households and coincided with the renewal of Polish recycling legislation. After generating the idea internally early on, Ikea integrated users into product development. Rather than drawing on a network of non-profit-oriented stakeholders, they contracted a market research company to visit thousands of Polish homes and collaborated with waste management company Stena Recycling in lobbying the City of Warsaw to set up a recycling station to ensure that the waste separated by households had further use. Ikea already had segregation kits for other markets, and it could follow an existing practice of home visits originating from the Swedish parent company as well as working with its typical commercial partners through the SOI process.

Configuration I2. Like I1, this configuration integrated stakeholders into SOI processes only after the idea generation stage. However, this was combined with the peripheral condition of *not* collaborating with a stakeholder that would act to extend the innovation's impact beyond its original scope. In other words, stakeholders' opportunities of influencing the innovation are minimized in two respects: excluding external inputs in the early phase (idea generation) and keeping the innovation in the hands of the firm. This configuration is ambivalent to heavy domination of non-profit-oriented stakeholders – this condition can be present or absent.

Frosta is a German-based frozen food company which strategically refrains from using food additives and applies the Marine Stewardship Council (MSC) ecolabel in fish products. Upon acquiring a Polish fish producer, Frosta needed to innovate new sustainable offerings that would cater to the taste of the Polish market. It did so in collaboration with several non-profit stakeholders: two government institutes (for Health and for Hygiene), two universities and the MSC, included in testing and launch phases. A considerable part of the innovation focused on consumer communication: how to win acceptability among the Polish clientele for whom environmental aspects of food products were not decision-making criteria. Frosta exemplifies that unless included early in the innovation process, the presence of non-profit-orientated stakeholders is not associated with system-level impact. The results were, among other things, interactive games on sustainable fisheries and responsible consumption, online platforms, mobile apps on healthy living - the users are provided with an online application/vocabulary educating consumers on additives used in the prepared food. Frosta wanted to develop the taste of its foods and sustainability in customer communication and, somewhat similarly to Ikea Poland, went ahead with its innovation, working with some key stakeholders, but without allowing space for the impact to be extended further.

DISCUSSION

New ways are needed to bring systems thinking closer to firm level action. While sustainability innovations and systems thinking are making their way into the management literature, current models lack empirical support and do not specify how companies intervene in systems or how to assess the system-level impact of such an intervention (Williams et al., 2024). Extant theories are not able to explain the conditions under which the sustainability-oriented innovation of firms can have system-level impact and previous literature is quiet about the details regarding with whom, in what way and when in the innovation process to collaborate. Addressing these knowledge voids, we contribute first by introducing a framework for associating management decisions regarding SOI with system-level impact. Through empirical analysis we then demonstrate the equifinality in arriving at system-level impact to offer insights that go beyond explanations in the literature to date (Adams et al., 2016; Biggs et al., 2021; Valente, 2010).

Operationalizing system-level impact

Actions by firms, and particularly sustainability innovations, are needed to change systems (Chapin et al., 2009), and some literature has recently begun to offer wise reasoning for linking firms to their social-ecological systems. But an intermediate step, ways to assess the impact of firm action on the system-level, is needed to move inquiry forward. The framework developed here is – to the best of our knowledge – the first to do just that, establishing a tool specifically to operationalize the system-level impact of sustainability-oriented innovation (SOI). Through the careful study of previous literature, we have established a set of 8 components which aim to be both as parsimonious as possible while still ensuring that all key elements identified in previous literature are captured. We then bring the framework to an empirical level by providing detailed

examples of each of the components and operationalizing it to analyze our data. In this way, we offer a nuanced specification of system-level impact.

For management studies, our framework furthers the insightful but so far limited literature on systems and especially the recent and nascent focus using a systems perspective on sustainability (Ahlström, Williams, & Vildåsen, 2020; Dentoni et al., 2021; Williams et al., 2024). It bridges the gap between conceptual work and empirical study, making the assessment of the system-level impact of sustainable business initiatives beyond the level of the organization empirically accessible. For SOI literature (Adams et al., 2016; Ayuso et al., 2006; Hall & Martin, 2005; Tischner, 2008), our study opens new avenues for extensive analysis of the system-level impact of innovation.

Two recipes for system-level impact

By introducing a new, previously neglected categorization for studying the stakeholder groups integrated in SOI processes, that of stakeholder profit-orientation, combined with the timing of stakeholders' inclusion and possible use of an impact extender, we discover two novel and different configurations or "recipes" associated with the system-level impact of a sustainability-oriented innovation. These recipes contrast collaboration with many non-profit-oriented stakeholders at the early phases of the innovation process (S1) versus cooperating with a stakeholder that extends the impact of the innovation beyond its original scope (S2). Intriguingly, our configurational approach reveals that these two intuitively complementary conditions appear to substitute for one another in terms of bringing a major external sustainability influence to bear in the innovation process. Without a configurational approach, the substitute nature of these conditions would be overlooked.

The Recipe of Radically Open Collaboration. Innovating firms can be open to external influence as the firm opens its core innovation process to stakeholders, the majority of which fundamentally differ in an important characteristic: profit orientation. Furthermore, the firm does this early on, when the innovation is being ideated. In other words, not only does the firm seek non-profit oriented partners in the innovation process but it allows them to influence the ideas right from the start rather than to legitimize or advance a well-developed innovation. The importance of this configuration is supported by the finding that one of the two configurations for insular innovation is its mirror image, characterized by the combined absence of the conditions *Network heavily dominated by non-profit-oriented stakeholders* and *Idea generation with stakeholders*. The symmetrical nature of these two configurations points to the noteworthiness of early involvement of many non-profit-oriented stakeholders in the innovating process as one recipe for achieving system-level impact from an SOI. If the firm ideates the SOI internally and restricts the number of stakeholders who are non-profit oriented, the opportunity for ideas regarding different aspects of the system is reduced, increasing the likelihood of the impacts of SOI remaining primarily at the insular level.

Introducing a new stakeholder categorization type based on profit orientation allowed us to find empirical support for the claims that governmental and other non-profit-oriented actors, whose core mission goes beyond commercial interests, can be effective partners for sustainability innovation which has system-level impact (Dentoni et al., 2021; Doh, Tashman, & Benischke, 2019). The complex interrelations between social and ecological systems associated with grand challenges (George et al, 2024; Whiteman et al., 2013) are harder for managers of a single firm to perceive, despite potentially good intentions. Diverse stakeholders who view the system from different loci, can assist companies in bringing system-level considerations into the innovation

process and help firms to get out of their comfort zones, leveraging their expertise sufficiently early to identify optional pathways for the innovation (Phillips et al., 2019). We contribute to management and innovation literatures (Ayuso et al 2011; De Marchi 2012; George et al 2016; Khavul & Bruton 2013) by theorizing that including stakeholders as representatives from different parts of the system when ideating, to bring ideas to the table even before development of the product has begun, can be critical for impact.

The Recipe of Targeted Collaboration. Does a firm have to engage in radically open collaboration to advance the potential of the system-level impact of its SOI? No – like happy marriages, recipes for system-level impact of an innovation can be composed of different ingredients too and this equifinality is clearly present in our findings. In the second configuration for system-level impact, firms collaborate with a specific partner whom they allow to extend the innovation's impact beyond where it was originally intended. Such an impact extender stakeholder (Goodman et al., 2017; Inigo et al., 2020) works closely with the innovation in different, proactive ways, with activities that magnify the sustainability impact of the innovation. In this recipe the (non) profit orientation of the impact extender stakeholder is not critical. Our findings suggest that the impact extender stakeholder can be a firm from another sector, or a social enterprise or a foundation. Early timing of stakeholder contributions matters in this recipe also, but as a peripheral, not core condition.

Contrasting the two configurations, Radically Open Collaboration and Targeted Collaboration, for system-level impact of innovation with one another, we theorize that a network heavily dominated by non-profit-oriented stakeholders can be substituted by collaborating with a particular stakeholder who extends the SOI toward system-level impact. The recipe of targeted collaboration potentially offers a route to system-level impact which is more accessible to resource

constrained firms that may not have the time, skills or tolerance to manage the complexity of working with a network of diverse stakeholders from fundamentally different organizational paradigms stemming from differences in profit orientation (Radziwon & Bogers, 2019).

Working with a stakeholder that can amplify or extend the impact of an innovation beyond its original scope hints, albeit somewhat differently than the radical openness recipe, at the importance of the innovating firm's openness versus being closed off to external influence. This kind of creative appropriation (Bakardjieva, 2005: 18; Feenberg, 2002: 125–129) requires a willingness by the innovating firm to be open to allow others to take the innovation beyond what was originally imagined or intended by the firm and to leverage the innovation for a wider purpose for example by adding a social impact in addition to an environmental one.

Government roles in SOI

While management literature often foregrounds firms' partnerships with NGOs, our findings suggest that government has a role in the system-level impact of SOIs. Beyond our QCA results, a qualitative examination of the relatively heterogeneous category of non-profit-oriented stakeholders points to a governmental role in both system-level configurations, albeit less so for the Targeted Collaboration recipe. This finding contributes to the management studies literature which is reintroducing different roles and dynamics of government in cultivating sustainable business conduct (Kourula et al., 2019). Our recognition of government as an innovation partner in SOI adds to the spectrum of public-private collaboration for grand challenges by George et al. (2024), highlighting opportunities for more creative roles for government than recognized in the traditional public-private partnerships literature.

From the perspective of the debate about governments' entrepreneurial and innovative capabilities (Johnson, 2008; Mazzucato, 2014; Mazzucato & Robinson, 2018), our findings

showcase that governments can participate in innovation in different ways: through significant financial support which stimulates an innovation from the outset, by granting permits and licenses, and removing challenges and potential barriers to an innovation's development through regulatory changes and concessions. The integrated nature of innovations with system-level impact in cities suggests the importance of embedding innovations in local systems and a relationship with local government decision makers which can adapt and facilitate the innovation as it develops. Digging deeper into these questions around local government activities stands at the crossroads of management studies and political science and could provide a fruitful avenue of future research in both literatures.

Our contributions reach beyond the management literature and may benefit evolving discussions coming from a socio-ecological systems perspective (Biggs et al., 2021; Chapin et al., 2009; Ostrom, 2009). Firms are powerful actors and their favorable or adverse impacts within such socio-ecological systems as well as their role in transformations can be major. Our empirical insights give a detailed view of company involvement in socio-ecological systems, which adds nuance to the typically broad categories used in SES literature where firms are grouped together as the "private" or "economic" sector. They may also provide future avenues to complement previous conceptual work on firms and systems (Dentoni et al., 2021; Tashman, 2021) as we pioneer the use of configurational analysis of a middle-N multi-country sample, not yet explored in the context of socio-ecological systems literature.

Implications for practitioners

Our discoveries bring a systems-level approach to business managers by creating visibility on how system-level impacts can result from innovation, as well as offering a thinking model and set of components for scrutinizing the ways through which such impacts can be achieved. This

visibility is valuable as the connection between firm-level action, including SOI, and the abstract system-level impact, is seldom evident to managers in practice.

From the firm perspective, the recipes for system-level impact suggest either high openness towards stakeholders, including those beyond commercial partners, already when ideating the innovation or working with a stakeholder that extends the impact of innovation. Both of these recipes entail broadening the horizons of the innovating managers and giving up some control of the innovation process or outcome. This will likely require a greater tolerance to risk. Our results further point to the usefulness of governmental organizations for SOI.

For non-profits, our scrutiny of the impact extender stakeholder role suggests a new potential use of SOI of firms. Instead of non-profits merely helping the firm to develop SOI, they can utilize an appropriate SOI as a platform for wider sustainability impact connecting across multiple social or environmental challenges or pushing for greater visibility and acceptance into customers' and citizens' daily lives.

Finally, our findings can be relevant for government actors and policy by highlighting the role of government in SOI and identifying more clearly the kinds of organizations and the contributions they can make to collaborative work. Both funding instruments and adaptions to local regulatory conditions at city level offer valuable pasture for government to play an active role in SOI with system-level impact.

Limitations and future research

There are some limitations to our study. First, methods for assessing the system-level impacts of sustainable business initiatives like innovations are in their early phases of development (Dentoni et al., 2021). While our study takes this area of research conceptually and empirically a leap further, our assessment of impacts remains indicative and further work using multiple

methodological approaches is needed to establish definitive results. Our framework and configurational results provide a platform for such future research to build on and encourage further work on the circumstances under which different forms of collaboration can lead to system-level impact, the extent to which each component affects the system and whether the components are weighted equally.

Second, our case sample based on 14 cases features limited diversity. QCA as a method grasps limited diversity quite well and makes assumptions of missing cases when creating intermediate and parsimonious solutions. However, such limited diversity may not capture a complete picture of the phenomenon. This prompts the need for studies of SOI with larger data sets based on the conditions we have identified.

Third, our analysis comprises of conditions that focus on aspects of stakeholder integration. We do not scrutinize all potentially influential aspects like the internal aspects of the firm such as the capabilities of the organization to integrate knowledge from the stakeholder inputs. Given that the insightful but so far limited systems and SOI literatures have strongly emphasized the inclusion of stakeholders for achieving system-level impact (Adams et al 2016; Dentoni et al 2021; Valente 2010) and that a QCA sample of 14 cases cannot accommodate a high number of conditions, we opted to focus on the stakeholder integration aspects. Also, contextual factors like public awareness could play a role. Achieving a richer understanding of the interplay between these and internal features (capabilities, organization culture etc.), and external stakeholder aspects is recommended and will require the scrutiny of multiple influences and their interconnections.

CONCLUSION

Responding to the urgency (Olsson et al. 2017) in management studies and business practice to understand the connections of firm-level sustainability-oriented action on the

surrounding systems (Dentoni et al., 2021; Whiteman et al., 2013; Williams et al., 2024), we offer insights into ways in which firms' collaboration with stakeholders in sustainability-oriented innovation can contribute to system-level impact. The two alternative recipes for system-level impact we discover suggest firms can integrate stakeholder views and inputs in different ways through the innovation process. While this may not come naturally to more traditional corporate cultures where management resists ceding control over the innovation process to outsiders, our results offer useful knowledge for firms as to how their innovations might achieve system-level impact and in what ways they could open up their internal processes to stakeholders.

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Table 1 Components of System-Level Impact

Impact component	Description	References:
Fundamental shift in knowledge	The innovation introduces completely new knowledge bases and leads to learning and a fundamental shift in knowledge.	(Gatignon et al., 2002; Hall & Andriani, 2003; Tashman, 2021; Tischner, 2008)
New combination of products and services	The innovation offers a solution in which a tangible product is fully or partially replaced by services; i.e., this solution can be characterized as a product service system (PSS) which reduces the need for new products.	(Mont, 2002; Olsson et al., 2017; Tukker, 2004)
Reconfiguration of infrastructural elements	Reconfiguration changes the way infrastructure, or the set of collective equipment necessary to human activities, such as buildings, roads, bridges, rail tracks, channels, ports, and communications networks, are linked to each other. Beyond physical infrastructure it also encompasses more abstract entities, such as protocols and standards.	(Bowker, Baker, Millerand, & Ribes, 2010; Chapin et al., 2009; McMeekin et al., 2019; Tischner, 2008)
Changes in inter-organizational processes and structures	The innovation changes how organizations work with others in order to develop their performance, processes, product or service for their customers.	(Meyer, 2002; Olsson et al., 2017; Tischner, 2008; Valente, 2010; Vanhaverbeke, 2006)
Changes in institutional policy, regulation and context	The innovation has emerged alongside changes in policy that influence how the field operates or the innovation has influenced changes in policy. Institutional context concerns formal or informal behavioral rules governing human actions and relationships with each other.	(Biggs et al., 2021; de Medeiros et al., 2014; Olsson et al., 2017; Valente, 2010)
Altered market structure	The innovation altered the structure or form of the industry and market; e.g., number or firms, market shares, the nature of costs, integration within value chain.	Geroski & Pomroy, 1990; Tischner 2008
Reconfiguration of actors and networks	The innovation changed how market side actors operate: alone or in a networked fashion.	(Antikainen & Valkokari, 2016; Tischner, 2008; Valente, 2010)
Changed context of use	The innovation changed the final use situation; i.e., how utility and value is achieved in the use phase is different than with an earlier solution.	(Chapin et al., 2009; Hoffmann, 2007; Tashman, 2021)

Table 2 Overview of Cases

Firm	Industry	Domain	Size	Country	Innovation
A2A	Energy	Energy supplier	Large	Italy	Energy management application
Big E*	Energy	Energy supplier	Large	UK	Smart control system for solar power
BMW	Mobility	Automobile producer	Large	Germany	Electric vehicle
Ecoveritas	Food	Food, retailer and producer	Medium	Spain	New product from food waste
Finlayson	Living	Home textile retailer	Large	Finland	Towels from recycled jeans material
Fiskars	Living	Gardening and household tools	Large	Finland	Indoor gardening device
Frosta	Food	Food, frozen fish meal producer	Large	Poland	Additive free recipes
HSL	Mobility	Public transportation provider	Large	Finland	Demand responsive transport service
Ikea	Living	Furniture retailer	Large	Poland	Segregation kit for household waste
JCDecaux	Mobility	Outdoor advertising and street furniture	Large	France	Cycle share system
Rockwool	Living	Stone wool manufacturer	Large	Denmark	Housing shelter for refugees
Skanska	Living	Residential construction company	Large	Finland	Affordable housing for low-income families
Unilever	Food	FMCG retail	Large	Spain	Micro-entrepreneurship project
Verbund	Energy	Energy supplier	Large	Austria	Charging station for e-vehicles

*anonymized

Table 3 Innovation Case Details

Company	Innovation and Process Description	Integrated Stakeholders	Profit Orientation G=government	Impact Extender
A2A	**Product-Service Innovation:** Application to manage energy use for new-generation integrated home appliances **Sustainability-orientation of innovation**: Environmental sustainability gains by decreased household energy consumption via raising awareness of the energy consumption and load shifting possibilities. **Process:** The economic development ministry was involved right at the idea generation stage motivating the original idea. A2A contacted the University to gain access to Whirlpool, which was a close partner of the university. This company ran the testing by providing appliances to families and managing the process while the University provided easily understandable instructions and developed hardware.	Politecnico di Milano	Non-profit	-
		Whirlpool	For profit	-
		Italian families	Non-profit	-
		Economic Development Ministry	Non-profit/G	-
Big E* *Case anonymized at company request	**Product-Service Innovation:** Smart home technologies control system to manage solar power generation and consumption. **Sustainability-orientation of innovation**: Environmental sustainability gains by promoting local generation of solar electricity and facilitating household demand shifting to match with local generation. **Process:** Big E partnered with the local municipality and the National Energy Foundation to gain support from local communities and encourage households to participate in field trials. The households gave feedback through home interviews and focus groups. Collaboration with Open University helped to deepen users' understanding during testing by applying participatory methods and behavioral analysis. GreenWave Reality brought expertise to develop new technological solutions not yet existing on the market.	Municipality	Non-profit/G	-
		Open University	Non-profit	-
		National Energy Foundation	Non-profit/G	-
		GreenWave Reality	For profit	-
		Customers	Non-profit	-
BMW	**Product-Service Innovation:** Electric vehicle BMW i3, charging stations & services for car sharing, parking, and need-based larger car use. **Sustainability-orientation of innovation**: Environmental sustainability gains by fossil fuel replacement to (renewable) electricity. Significant efficiency gains caused by use of electricity (Electric 60%, conventional 14-30%). Social sustainability gains by reduced air and pollution levels. Services reducing the need of own car and for reducing mileage and emissions upon parking. **Process:** BMW's cross-functional innovation team discussed with key mobility decision-makers, consumers and urban citizens in 20 cities worldwide. Thereafter BMW set up a co-creation lab with customers. Field trials were set up in several countries in collaboration with municipalities (hosting the trials), universities (for behavioral and scientific analysis), research institutes (coordination different locations) and other experts, to explore customers' usability and technical issues, and explore specific needs such as long-distance driving. Infrastructure and energy provision firms and regulators collaborated to provide the necessary conditions for field trials.	Open innovation agency	For profit	-
		Expert on megacity mobility	Non-profit	-
		People with sustainable lifestyles	Non-profit	-
		Mayors and city planners of 20 cities in 6 countries	Non-profit/G	-
		Regulator	Non-profit/G	-
		End users	Non-profit	-
		University	Non-profit	-
		Research institute	Non-profit	-
		Public authority	Non-profit/G	-
		Partners from infrastructure and energy sector	For profit	-

Eco-Veritas	**Product-Production Innovation:** Cuina Veritas is a range of new products made from unattractive but quality fruit and vegetables often rejected by consumers. Production process redesigned to have social impact. **Sustainability-orientation of innovation**: Environmental sustainability gains via food waste reduction caused by usage of raw materials that would have been wasted. Social sustainability gains by employing disabled people. **Process:** Customers challenged EcoVeritas to address food wastage. Co-creation workshops were arranged following discussions between Ecoveritas' CEO and the Alicia Foundation, specialized in educating and promoting healthy eating. These workshops helped to develop recipes and ideas for new products made from potentially wasted seasonal food. The non-profit organization, Grupo SIFU, also collaborated to integrate mentally and physically handicapped people into the production process and added a social impact to the innovation not previously envisaged by the Ecoveritas.	The Alicia Foundation	Non-profit	-
		Grupo SIFU	Non-profit	Impact Extender
		Customers	Non-profit	-
		External communications expert	For profit	-
Finlayson	**Product Innovation**: Towels made from recycled jeans material. **Sustainability-orientation of innovation**: Environmental sustainability gains via recycling and reduced material use of textiles. **Process:** Long term supplier and weaver Jules Clarysse collaborated at the idea generation stage proposing a yarn developed from recycled jeans by the European Spinning Group (ESG). Finlayson completed the circle by facilitating the collection of jeans material from its customers. Altec partnered to help collect and process the material, while Miltton worked on media activities. The non-profit Modient partnered with Finlayson to offer life cycle and impact analysis of the product.	Jules Clarysse	For profit	-
		ESG	For profit	-
		Altec	For profit	-
		Miltton	For profit	-
		Modient	Non-profit	-
Fiskars	**Product Innovation:** Indoor gardening device with lighting for home-grown herbs. **Sustainability-orientation of innovation**: Environmental sustainability gains by reduction of food waste as salads etc. stay good inside the gardening device. Social sustainability gains by user financial benefit as home-grown herbs and salads may have lower price in comparison for ready grown alternative. **Process:** Fiskars R&D department studied contemporary gardening trends by observing users and discussing with the Association of Useful Plants. The result was an idea to create a product to facilitate indoor gardening over dark winter months. The firm ran user focus groups in early and late stages of the product development and tested ideas with Dodo, an association for environmental issues. Gardening schools and professionals helped to test the equipment. Bloggers helped to spread knowledge of the product among users.	Gardening school	Non-profit	-
		Association of Edible Plants	Non-profit	-
		Professional gardeners-entrepreneurs	For profit	-
		End users	Non-profit	-
		Dodo	Non-profit	-
Frosta	**Product Innovation:** New additive-free fish and frozen seafood meals. **Sustainability-orientation of innovation**: Environmental sustainability gains by use of MSC certified fish in the process. **Process:** Frosta's Polish operations hired SOMA Torun, a research agency, to conduct a survey of consumer expectations concerning additives in frozen meals. The results facilitated the development of additive-free recipes for frozen fish meals which were tested during workshops with famous chefs and food bloggers. Public health institutes published a dictionary of common food additives to educate the general public. University of Bydgoszcz students organized events in the local stores as part of their internships with support from MSC	National Institute of Public Nutrition	Non-profit/G	-
		National Institute of Hygiene	Non-profit/G	-
		University of Bydgoszcz student club	Non-profit	-
		Marine Stewardship Council	Non-profit	-

	and Agricultural University students to communicate with customers and explain the benefits of additive-free food.	Agricultural University	Non-profit	-
		Bloggers	Non-profit	-
		SOMA Torun	For profit	-
		Celebrity	Non-profit	-
		Consumers	Non-profit	-
HSL	**Service Innovation:** Demand-responsive mini-bus transportation (DRT) service. **Sustainability-orientation of innovation**: Environmental sustainability gains by reduced needs for private cars or taxis. This leads to emission reduction and reduced need for parking spaces in urban areas. Social sustainability gains by improved transportation comfort for special groups such as children, elderly, and disabled. **Process:** A university professor suggested the DRT system to HSL bringing the idea to the firm. The project received funding through an innovation competition run by the municipality. HSL focused on service development, while Ajelo developed the software. HSL collected suggestions from the public on how they would use DRT service. Aalto University mediated the discussions with the public in order to adapt the service. An initial trial with University staff and students provided further feedback.	Aalto University	Non-profit	-
		Aalto staff and students	Non-profit	-
		General public	Non-profit	-
		Municipality	Non-profit/G	-
		Ajelo partner company	For profit	-
IKEA	**Product Innovation:** A segregation kit for household waste specifically adapted to typical Polish homes with limited space. **Sustainability-orientation of innovation**: Environmental sustainability gains by provided segregations units to enable recycling of household waste which leads to formation of compost and reduced need of incineration. **Process:** IKEA introduced segregation kits for households in response to new legislation on waste segregation in Poland. In order to find the best system and design, IKEA made visits to customers' homes to observe kitchens and under-sink spaces. Customer research agency collaborate in developing the questions and agenda for the visits. IKEA produced an e-book with a popular household magazine Cztery Katy to educate and advise on recycling. To further support the recycling of waste, IKEA built a first recycling station in Poland near its store in collaboration with Warsaw municipality and the recycling company Stena.	End users	Non-profit	-
		Stena Eco-station (City Council of Warsaw)	Non-profit/G	-
		Customer research agency	For profit	-
		Magazine Cztery Katy	For profit	-
JCDecaux/ Velib	**Product-Service Innovation:** City-wide self-service bicycle sharing system **Sustainability-orientation of innovation:** Environmental sustainability gains by modal shift from private cars to public transportation and shift from public transportation to bicycling which leads to reduced energy needs and emissions. Social sustainability gains via positive health impacts from increased physical activity levels. **Process:** JCDecaux and the City of Paris entered into a partnership to develop a zero-carbon cycle share system for the city in return for outdoor advertising rights. Cyclists and residents collaborated in generating ideas along with input from the City. At the request of the municipality an end user committee was established with volunteers who met regularly with JCDecaux, the City of Paris and a communications agency to discuss new ideas and service extensions, trial new innovations and share them among the community. CitéGreen, a start-up focused on sustainability took a proactive role in promoting the use of Vélib' and creating incentives for customers to buy other sustainable lifestyle products and services.	City of Paris	Non-profit/G	-
		CitéGreen	For profit	Impact Extender
		End user	Non-profit	-
		Communications agency	For-profit	-

Rockwool	**Product Innovation:** A housing shelter for use in refugee camps made from stone wool to protect from heat, cold, noise and fire risk. **Sustainability-orientation of innovation:** Environmental sustainability gains via high insulation efficiency in heating and cooling, and durability. Social sustainability gains include improved circumstances for refugees, protection from heat and cold, reduced noise level inside and high fire-resistance. The shelter is also higher than typical tents used in refugee camps. **Process:** The Rockwool prototype coordinator and the Innovation Director at Orange Innovation (OI) together generated the idea for developing shelters made out of stone wool. OI proactively supported the innovation process by facilitating rapid prototyping and arranging for the shelters to be tested in a living lab set up by volunteers for guests of a local rock music festival. OI extended the potential impact of the shelters for refugee contexts and two universities helped to introduce the innovation to health and refugee organizations to ensure its appropriateness for use.	Orange Innovation	Hybrid	Impact Extender
		Universities CBS & DTU	Non-profit	-
		Festival guests	Non-profit	-
		Festival volunteers	Non-profit	-
		Health & refugee organizations	Non-profit	-
Skanska	**Product Innovation:** Affordable, functional, comfortable and eco-efficient housing for low-income families who want to own their home including common spaces and public transport access. **Sustainability-orientation of innovation:** Ecological sustainability gains by the replacement of concrete, steel and stone with wood material. Local pre-fabrication of modules used in construction which reduces construction waste and leads to shorter construction times. Social sustainability improved by taking community aspects into account. Areas for interaction e.g. sauna in the yard and vegetable plots. **Process:** Skanska and IKEA generated the idea together. Skanska then ran online focus groups with end users to discuss affordable and comfortable housing development. In collaboration with an architect, IKEA helped to design optimal standardized solutions for kitchens and storage to fit compact-sized apartments and Stora Enso contributed technical innovations. Hanken University organized a workshop for different stakeholders to aid understanding of the project. As a result, the City of Vantaa helped with regulatory and infrastructure support to find the appropriate plots for construction. IKEA proactively collaborated again at a later stage to extend the impact of the innovation through exposing the project through their store platform.	City of Vantaa	Non-profit/G	-
		IKEA	For profit	Impact Extender
		Architecture firm	For profit	-
		Hanken University	Non-profit	-
		End users	Non-profit	-
		Stora Enso	For profit	-
Unilever	**Business Model Innovation:** Reducing youth unemployment through low carbon emission mobile ice cream vendors. **Sustainability-orientation of innovation:** Social sustainability gains by labor integration of individuals with potentially high-risk social exclusion. **Process:** Unilever had had previous success with micro-entrepreneurship initiatives in food delivery in Asia. In light of heavy unemployment in Southern Europe the firm worked with local municipalities and communities to generate ideas for an innovative business model for mobile vending of ice cream with low carbon emission vehicles. Spanish municipalities help in negotiating permits to deploy the initiative in their towns. An employment agency helped to recruit the vendors. Fundació Exit proactively collaborated with its expertise in working with high-risk exclusion groups (e.g. immigrants) to help identify the participants who could be most impacted and to run workshops and coaching sessions.	Local entrepreneurs	For profit	-
		Small and medium sized companies	For profit	-
		Municipality	Non-profit/G	-
		Fundació Exit	Non-profit	Impact Extender
		Consumer association	Non-profit	-
		Vending machine expert	For profit	-
		Government employment agency	Non-profit/G	-

		User entrepreneurs	Non-profit	-
Verbund	**Service-Business Model Innovation:** A nationwide network of hydropowered charging stations for e-vehicles plus related service applications **Sustainability-orientation of innovation:** Environmental sustainability gains by using of low carbon source for electric charging. Social sustainability gains via improved urban air quality because of electric fleet. **Process:** From a very early stage Verbund collaborated with multiple Austrian companies and institutions in a cooperative project to receive funding for e-mobility from the Climate & Energy Fund. Winnovation collaborated with Verbund to conduct a lead user study. Verbund and the project partners implemented a pilot study to test hardware and software solutions developed with customers and analyze their feedback on usability.	Austrian mobility club	Non-profit	-
		Austrian institute of technology mobility department	Non-profit	-
		Companies	For profit	-
		User study organization	For profit	-
		Austrian government	Non-profit/G	-
		End users	Non-profit	-

Table 4 Calibration Table

Condition / outcome		Calibration type	Calibration		
Condition 1	Network heavily dominated by non-profit-oriented stakeholders	Continuous fuzzy-set	Threshold full non-membership	Crossover point	Threshold full membership
			-0,4	0,59	0,75
Condition 2	Inclusion of impact extender	Crisp-set	Presence of impact extender in the collaboration = 1 Absence of impact extender in the collaboration = 0		
Condition 3	Idea generation with stakeholder(s)	Crisp-set	Presence of collaboration in idea generation phase of the innovation = 1 Absence of collaboration in idea generation phase of the innovation = 0		
Outcome	System level impact score	Continuous fuzzy-set	Threshold full non-membership	Crossover point	Threshold full membership
			1	3,5	5

Table 5 Fully Calibrated Data Set

CASE	Network heavily dominated by non-profit-oriented stakeholders	Inclusion of impact extender	Idea generation with stakeholder(s)	System-level impact score
A2A	0,43	0,00	1,00	0,36
Big E	0,55	0,00	0,00	0,36
BMW	0,55	0,00	1,00	1,00
Ecoveritas	0,43	1,00	0,00	0,15
Finlayson	0,03	0,00	1,00	0,15
Fiskars	0,15	0,00	0,00	0,05
Frosta	0,97	0,00	0,00	0,05
HSL	0,55	0,00	1,00	0,73
Ikea	0,15	0,00	0,00	0,15
JCDecaux	0,15	1,00	1,00	1,00
Rockwool	0,98	1,00	1,00	0,15
Skanska	0,15	1,00	1,00	0,73
Unilever	0,27	1,00	1,00	0,15
Verbund	0,32	0,00	1,00	0,73

Table 6 Configurations associated with system-level and insular impact of SOI

	Configurations associated with system level impact of SOI		Configurations associated with insular impact of SOI	
	S1	S2	I1	I2
Network heavily dominated by non-profit oriented stakeholders	●	⊗	⊗	
Inclusion of impact extender	⊗	●		⊗
Idea generation with stakeholder(s)	●	•	⊗	⊗
Consistency	0.96	0.71	0.78	0.85
Unique coverage	0.32	0.31	0.24	0.15
Illustrative strong cases	BMW, HSL	Skanska, JCDeceaux	Ikea, A2A, Finlayson	Frosta, Big E, Fiskars
Solution consistency	0.82		0.75	
Solution coverage	0.62		0.65	
Key:	●	Causal condition present		
	⊗	Causal condition absent		
	•	Peripheral causal condition present		
	⊗	Peripheral causal condition absent		

Figure 1 Conditions and Outcome Overview

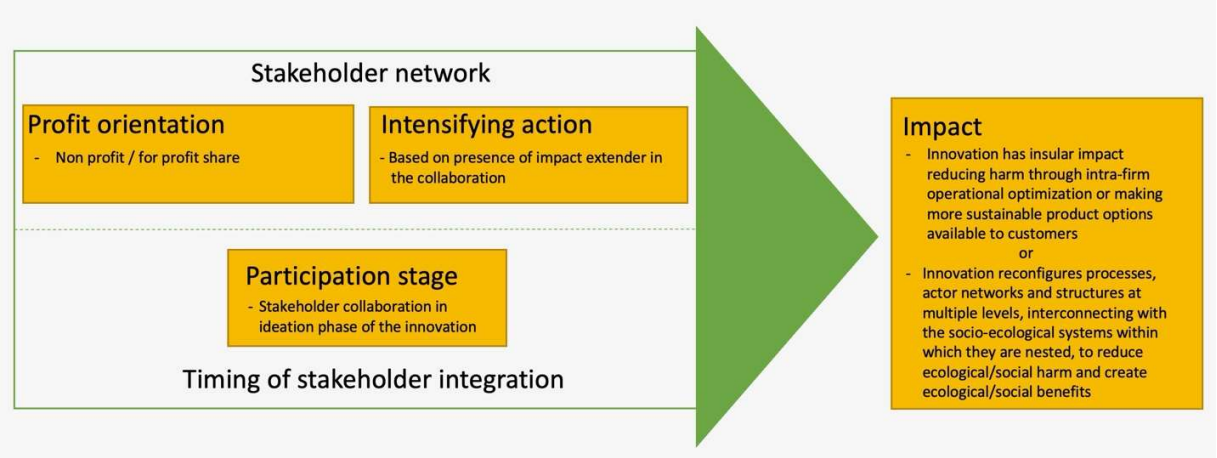
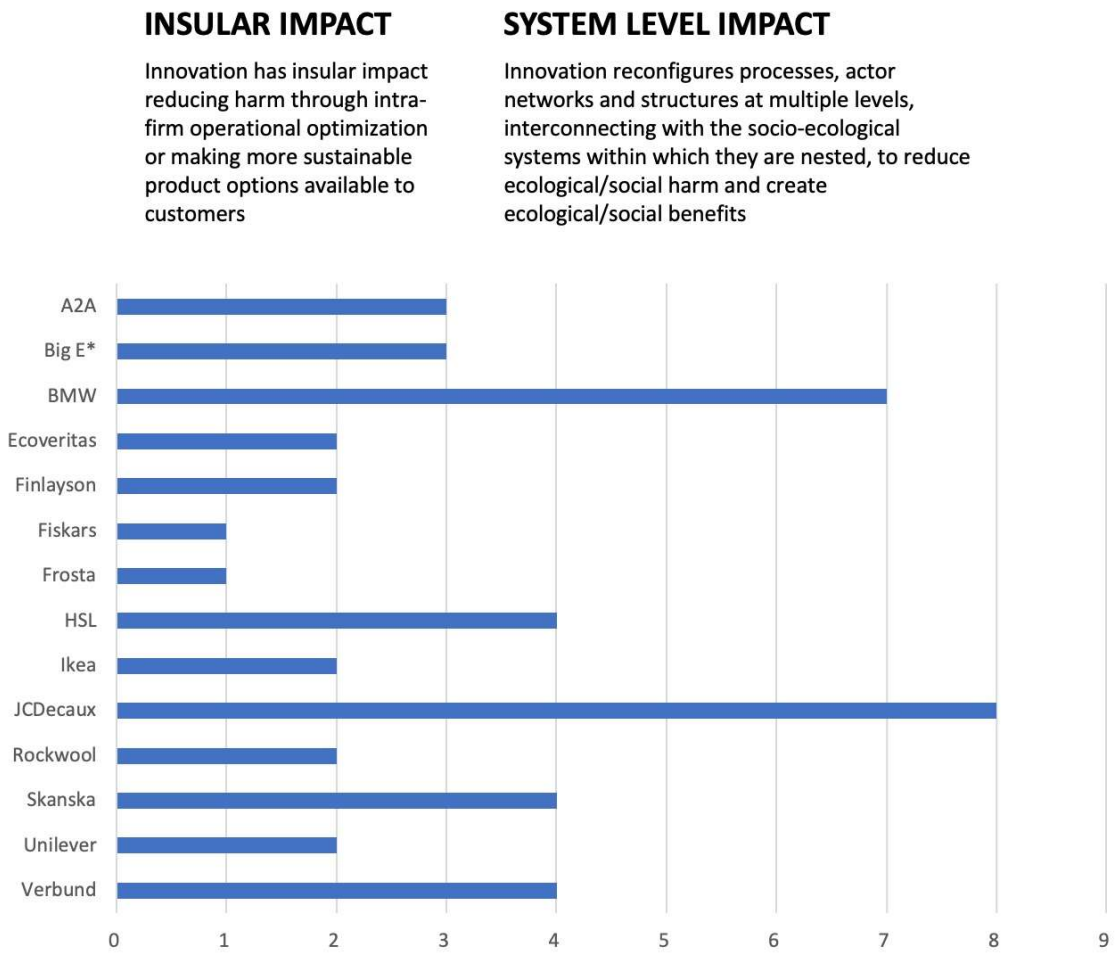


Figure 2 Case Outcome Score



Appendix 1: Measurement of outcome – an example case (JCDecaux).

Impact component		Description (Example of cycle share system)
1	Fundamental shift in knowledge	The company created novel knowledge that was patentable. Qualitative evidence from interviews: "Another central innovation, unique to JCDecaux is the system which links the use of a bank card directly with the bike station." Makes cycling more accessible by linking the use of a bank card directly with the bike station and can be used equally by tourists and visitors to the city as well as citizens.
2	New combination of products and services	Vélib' system is a product-service innovation that consists of bikes, biking stations and services such as payment solutions.
3	Reconfiguration of infrastructural elements	The system includes bike parking stations around the city. Qualitative evidence from interviews: "Vélib' stations are built primarily on what were previously parking spaces and this has led to the conversion of over 6,000 car parking spaces."
4	Changes in inter-organizational processes and structures	90% of the material used in the bikes can be recycled including all the plastic and steel. Tires and inner tubes are given a second life: "There are creative workshops where leather goods, belts and bags are made. We have four partners who come to collect material to make jewelry and other things."
5	Changes in institutional policy and context	There is the "objective to reduce the use of cars in Paris and promote cycling and pedestrian areas" at the city level.
6	Altered market structure	Vélib' is part of a wider project which aims to deter the use of individual cars in Paris with a reduction of parking spaces, the increase in the cost of parking, and more cycle and bus lanes. Between 2001 and 2006 the share of trips made in the city of Paris by bicycle increased 48%. Qualitative evidence from interviews: "Vélib was the biggest program of self-service bikes ever installed in the world when we started in 2007"
7	Reconfiguration of actors and networks	User made their own communities around Vélib' independently of the City of Paris and independently of the company. They gave advice and explained how to use Vélib'. Qualitative evidence from interviews: "they (communities) did all that on their own".
8	Changed context of use	The mobile applications which allow users to know in real time where there are bikes and where there are available spaces. Qualitative evidence from interviews: "The City of Paris was looking for a system that would be available right through the night when other alternative forms of public transport were not running or were scarce." "Vélib' in Paris is a transformation, it changes lifestyles … it has changed the way that you move around the city".
Total score: 8		

Appendix 2: Truth table

Network heavily dominated by non-profit-oriented stakeholders	Presence of impact extender	Idea generation with stakeholder(s)	Number of cases	Outcome	Cases	Raw consistency	PRI consistency
1	0	1	2	1	BMW, HSL	0,96	0,92
0	1	1	3	1	Skanska, Unilever, JCDecaux	0,71	0,65
0	0	1	3	0	A2A, Verbund, Finlayson	0,67	0,50
1	0	0	2	0	BigE, Frosta	0,33	0
0	0	0	2	0	Fiskars, Ikea	0,27	0
1	1	0	0	?			
1	1	1	1	?			
0	1	0	1	?			

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