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Experimental networks for business model innovation: A way for incumbents to navigate sustainability transitions?

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ABSTRACT

To navigate sustainability transitions, firms are often prompted to take an active role in business model innovation. Previous research has shown, however, that when attempting to change business models, incumbent firms frequently face challenges concerning the ambiguity of transition pathways. This paper is an inquiry into this intersection between business model innovation and sustainability transitions. Anchored in three case studies of sustainability-driven, pre-commercial projects of emerging technologies, it reveals how groups of organizations collaborate in time-limited, cross-industry networks, to explore potential business models for anticipated, profound, changes in socio-technical systems. Drawing on these findings, the paper introduces the concept of *experimental networks* and illustrates how experimental networks can facilitate business model innovation in relation to systemic change. By outlining the constituents of the experimental network concept, the paper contributes to theory by uncovering the interplay of interorganizational collaboration and network level business model innovation. In addition, it reveals how experimental networks constitute one way for incumbents to claim agency with respect to emerging sustainability transitions.

1. Introduction

It is widely acknowledged that a transition towards environmental sustainability requires systemic change to existing production and consumption patterns. In research, this has driven scholarly attention to address issues of sustainability transitions, i.e., trying to understand how to achieve profound changes in existing socio-technical systems for example, infrastructure, road transportation, and energy (Köhler et al., 2019; Markard et al., 2012). In practice, many companies also seek strategies to navigate such transitions, often by probing the potentials of new technologies, new business models, and new collaborative patterns aimed at gaining (and shaping) competitive positions for the future (Berggren et al., 2015; Tongur and Engwall, 2014). Consequently, how businesses can innovate so as to contribute to sustainability has emerged as a key question in research (Foss and Saebi, 2017, 2018; van Waes et al., 2018; Bolton and Hannon, 2016; Geels, 2018).

However, previous research has identified business models as constituting a key bottleneck in sustainability transitions (Bidmon and Knab, 2018; Wells and Nieuwenhuis, 2012). Since sustainability performance seldom overrides financial performance criteria in the short term (Schaltegger et al., 2016; Tongur, 2018), incumbent businesses tend to hold back more sustainable alternatives to existing, less sustainable technologies. Furthermore, since novel, alternative business models tend to conflict with the entrenched, institutionalized ways of doing business (Bidmon and Knab, 2018), business model innovation for sustainability transitions in established industries often requires systemic reconfiguration (Markard et al., 2012).

Previous research on business models has highlighted the importance of collaboration, boundary spanning, and interorganizational interactions for business model innovation (Calia et al., 2007; McGrath, 2010), which can be defined as activities ranging "from incremental changes in individual components of business models, extension of the existing business model, introduction of parallel business models, right through to disruption of the business model, which may potentially entail replacing the existing model with a fundamentally different one" (Khanagha et al., 2014, p. 324). Some scholars have addressed the significance of interactions with external actors using concepts such as coopetition-based business models (Ritala et al., 2014), and open business models (Chesbrough and Schwartz, 2007). Taken together, these studies have shed light on challenges in different types of external engagement for firm level business model innovation, without however, explicitly addressing network level business model innovation (e.g.,

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Chesbrough and Schwartz, 2007; Ritala et al., 2014). Other scholars have, however, addressed how business model innovation plays out at both firm and network levels in parallel using concepts such as networked business models (Palo and Tähtinen, 2013), network-embedded business models (Bankvall et al., 2017), and business model innovation alliances (Spieth et al., 2021). These scholars have shown that organizations act on emerging business opportunities by developing both established and new relationships in industrial networks, which are understood in this paper as complex and long-term structures that are characterized by interdependencies between industrial actors in entrenched patterns of business relationships (Håkansson and Snehota, 1989; Håkansson and Ford, 2002). So far, however, the business opportunities emphasized in this literature have been near commercial deployment (e.g., Solaimani et al., 2018), and thus extant literature has paid limited attention to business model innovation in relation to the intricacies of more profound, systemic transitions that typically unfold over long periods of time.

Research on sustainability transitions, on the other hand, acknowledges the profound, systemic, and long-term character of transitions, traditionally studying how socio-technical systems around more sustainable technologies emerge and function (Bergek et al., 2008), as well as how transitions towards more sustainable technologies can be governed (Rotmans and Loorbach, 2009; Smith et al., 2005). Although the role of business model innovation has been recently recognized in this literature (cf. Köhler, 2019), a key question of how firms benefit from participating in experimentation for business model innovation remains unexplored (Sengers et al., 2019). Thus, addressing the gap that exists between business model innovation research and the sustainability transitions literature is important for understanding, on the one hand, how business model innovation can enhance sustainability transitions and, on the other hand, how business model innovation can be facilitated in this context.

Accordingly, the purpose of this paper is to investigate a type of interorganizational collaboration aimed at enabling business model innovation that has, so far, gained limited attention in research. Based on findings from three case studies of sustainability driven, precommercial projects involving emerging technologies in the sectors of steel production, long haul trucking, and public transport, the paper shows how groups of incumbent companies engage in temporary, cross-industry networks to simultaneously test visionary technologies and business models that might have systemic industrial effects in the future. The cases exhibit similar patterns of interorganizational collaboration for facilitating business model innovation to navigate anticipated sustainability transitions. To capture this phenomenon, we introduce the concept of *experimental network*, which we define as *a group of organizations collaborating in a time-limited, cross-industry network to explore potential business models for an anticipated, profound change in socio-technical systems.*

By introducing the concept of experimental networks, the paper makes three primary contributions. First, it contributes to the network-oriented stream of research on business model innovation (e.g., Bankvall et al., 2017; Palo and Tähtinen, 2013) by delineating a distinct type of network for business model innovation. Thus, we extend the understanding of the interplay between interorganizational collaboration and network level business model innovation in the important context of anticipated sustainability transitions. Second, by outlining the constituents of the experimental networks, it bridges the regime and niche dichotomy in sustainability transitions discourse (Geels, 2014) and reveals one way for incumbents of a regime to claim agency with respect to emerging transitions. Furthermore, the paper shows how experimental networks can facilitate business model innovation by enabling access to complementary resources, providing test beds for learning, leveraging legitimacy, and claiming space in anticipated potential transitions.

2. Theoretical background

2.1. Sustainability transitions and business models

Research on sustainability transitions (e.g., Markard et al., 2012; Smith et al., 2005) have attracted widespread interest in various scholarly communities (Köhler et al., 2019). Inspired by evolutionary economics, innovation studies, and institutional theory this research stems primarily from an interorganizational, industry level of analysis (Zolfagharian et al., 2019). Much recent research aimed at achieving sustainability transitions has explored mechanisms and processes that initiate change in institutionalized and well entrenched industries (e.g., Rip and Kemp, 1998; Köhler et al., 2019). While some scholars have studied sustainability transitions retrospectively as changes from one historical state to another (Geels, 2012), some others – including this paper – view transitions more as a nascent journey that displays signs of future potential (Susur and Karakaya, 2021; Garud et al., 2018). According to this literature, sustainability transition may be in the making when an established regime is destabilized through a combination of external pressure for change, such as the urgency of climate change mitigation (Turnheim and Geels, 2013), and the presence of alternative niche technologies with the potential to resolve that pressure (Geels et al., 2016). If these processes are aligned, they may create a window of opportunity that allows emerging innovations to break through and cause the established regime to undergo a systemic transition (e.g., Geels and Schot, 2007; Tongur and Engwall, 2017).

Alternative technologies, however, face high commercialization barriers since they seldom align with the configurations of the incumbent regimes (e.g., Dijk et al., 2013; Bouwman et al., 2014). Thus, to facilitate the improvement of promising innovations, a common suggestion is to create protected spaces to shield the innovations from the commercial selection environment of established markets (Hoogma et al., 2002; Van der Laak et al., 2007; Nill and Kemp, 2009). Thanks to the weak structuration in such protected "niches" (Geels and Schot, 2007), experimentation is enabled so that the innovations in question can mature and gain momentum. In this way, the novel technology is expected to reach a sufficient maturity to eventually be able to compete with the incumbent technologies (Geels, 2005; Berkhout et al., 2010).

For incumbents, barriers to entering niches are not really technological per se, but rather related to business model inertia (e.g., Bohnsack et al., 2014). As stated by Christensen (2006, p. 48), the fundamental challenge of a disruptive technology is often "a business model challenge, not a technology problem"; meaning that the key issue for market success lies in the interactions between a novel, alternative technology and necessary business model innovation (Markides, 2006; Sandström, 2010). Previous research has also identified that business models can play different roles in sustainability transitions. Sometimes, a business model can be a non-technological niche innovation in itself, while in other situations, business models can function as mediating devices enhancing the breakthrough of alternative technologies (Bidmon and Knab, 2018; Chesbrough, 2010; Teece, 2010). Usually, however, the existing business models of an established industry function as institutionalized lock-ins that hinder emerging alternative technologies from breaking through (Bidmon and Knab, 2018; Christensen, 2006; Tripsas and Gavetti, 2000).

2.2. Business model innovation

Research on business models has primarily taken two streams. Firstly, in research on information systems, the concept gained significant popularity during the information technology boom of the late 1990s, with an emphasis on the new business opportunities enabled by the Internet (e.g., Zott et al., 2011). In this stream, the primary emphasis has been on business models related to various products and services (Bouwman et al., 2008; El Sawy and Pereira, 2013). Secondly, in management research, the business model concept has gained attention, driven by an interest in emerging business logics, as well as new ways of proposing, creating, and capturing value (Bucherer et al., 2012; Spieth et al., 2014; Teece, 2010).

Even if the business model concept has been criticized for being ontologically vague (Al-Debei and Avison, 2010; Zott et al., 2011), it directs attention toward the backbone of all successful businesses; the activities connecting the firm's, or product's, technological core to the fulfilment of its customers' needs (Chesbrough and Rosenbloom, 2002). In research, a business model is often conceptualized as a framework encompassing a number of interrelated components (Morris et al., 2005; Osterwalder and Pigneur, 2010), an activity system (Zott and Amit, 2010), or as a representation of how a business functions (Massa et al., 2017). Regardless how it is conceptualized, a business model perspective implies a shift in attention in order to transcend traditional firm boundaries and to relate the internal value creation activities to both horizontal and vertical features of the industrial network (Zott and Amit, 2013).

There is a move toward scholarly consensus which aligns with Teece's (2010) conceptualization of a business model as the organizational and financial architecture of a business, that is, the configuration of its value propositions, value creation processes, and value appropriation mechanisms (Tongur and Engwall, 2014; Foss and Saebi, 2018). One way of framing such conceptualization, and which we apply in this paper, is to describe business models as consisting of four domains, depicting how service, technological, organizational, and financial arrangements (STOF) are configured to provide value to the customers (Bouwman et al., 2008). This conceptualization also includes how some parts of this value are captured by the providers with respect to the systemic nature of sustainability transitions, both environmental sustainability value arrangements, (e.g., in the service domain), and changes of the established systems (e.g., within the technological, organizational, and financial domains). In this "STOF model" (ibid.), the *service domain* considers how value is proposed through services and the way customers (or end users) perceive the value proposition. The *technology domain* addresses how a technical architecture design involving a system of technologies enables providers to deliver value to the customers. The *organization domain* describes how a value network consisting of multiple actors with complementary roles, resources, and capabilities collaborate and realize the value offering. Finally, the *financial domain* addresses how financial arrangements manifest among the actors in the value network, and how the actors capture monetary value from the offerings produced. While framing business models with such domains, we acknowledge that business models "are not passive representations [of how firms do business] but contribute to the emergence of a new entity" (Doganova and Eyquem-Renault, 2009, p. 1568). In other words, business models are not only shaped by the context, but might also shape the contexts they are embedded in (Kumaraswamy et al., 2018).

Thus far, the research on business model innovation has been dominated by a retrospective perspective. Even though most handbooks treat business model innovation as a planning exercise in which a new business model is designed and specified before the activity system is put into practice (Osterwalder and Pigneur, 2010), empirical research on business model innovation is typically executed ex post by studying business models that have been successfully established in the marketplace (cf. Desyllas and Sako, 2013). Thus, in research, business model innovation has been implicitly depicted as happening when a business model has succeeded in the marketplace, which creates a static and survivor-biased conceptualization (cf. Hacklin et al., 2018). To date, success stories have been emphasized, while insights on incumbents' nascent attempts to innovate business models are scarce.

While some scholars have studied business model innovation processes in startup settings (e.g., McDonald and Eisenhardt, 2020), others have focused on business model innovation that involves incumbent firms (Spieth and Meissner, 2018; Foss and Saebi, 2017). As pointed out by Massa et al. (2017); when studying business model innovation, it is important to distinguish between the process of designing a business model from scratch and the act of reconfiguring already existing business models for an established business. For an established business, business model innovation is often triggered by an external factor (Sabatier et al., 2010; Kaulio et al., 2017); the existing business model is challenged and a process of reconfiguration starts. If successful, the outcome is a new business model rooted in the firm's resources and capabilities (Johnson et al., 2008). However, what features will define success can seldom be comprehensively predicted in advance (McGrath, 2010). Consequently, business model innovation is an explorative process, usually characterized by trial and error (Sosna et al., 2010). There is a need to experiment with various alternatives, anticipating that some can fail (Haaker et al., 2017), and that such failures will provide learning opportunities that can be meaningfully applied in the future (Chesbrough, 2010). Consequently, theory suggests that experimentation is crucial in order to transform market boundaries through innovative value propositions (Mauborgne and Kim, 2005).

Until recently, business model innovation has predominantly been theorized as a process that revolves around changing the actions, structures, and resources of a single firm, product, or business unit (Demil and Lecocq, 2010; Doz and Kosonen, 2010). With respect to established businesses, several issues have been identified to frequently create barriers to successful business model reconfiguration. For example, difficulties in reallocating necessary resources from existing business models (Doz and Kosonen, 2010), lack of top management commitment (Foss and Saebi, 2017), cognitive inertia among crucial actors (Chesbrough, 2006), conflicting logics between old and new models, and lack of capabilities for operating multiple business models in parallel (Santos et al., 2009).

2.3. Business model innovation in networks

There is a small, but growing stream of research concerning business model innovation in the context of interorganizational interactions (Calia et al., 2007; McGrath, 2010; Spieth et al., 2021). As stated by Berglund and Sandström (2013, p. 277), "the existing focus [of business model research] on intra-firm issues only tells half the story". Indeed, incumbent firms engaging in business model reconfiguration often experience restricted freedom since they are subject to the interdependencies of actors and relations in established value networks (ibid.). Nevertheless, studies have shown that many large incumbent firms attempt to secure value proposition, creation, and capture by deliberately orchestrating their value networks (Sabatier et al., 2012). Thus, rather than using only internal resources for changing a business model, an incumbent firm can try to generate business model reconfiguration by drawing on contextual resources and competences (Spieth et al., 2021).

Scholars applying the concept of "open business models" (Chesbrough, 2007) have, in particular, acknowledged how incumbent firms can transform their customer offerings and value creation processes by the purchase of intellectual property rights, strategic recruitment of personnel, temporary hiring of consultants and contractors, as well as more permanent acquisitions of organizational resources (Bolton and Hannon, 2016; Bohnsack et al., 2014; Calia et al., 2007). Consequently, concepts such as "coopetition-based business models" (Ritala et al., 2014), "networked-enterprises" (Solaimani et al, 2015, 2018), and "business model innovation alliances" (Spieth et al., 2021) have been proposed for cooperative ventures in which a number of firms collaborate through a shared business model.

This notion of business model innovation as a result of interorganizational interactions has directed attention toward an industrial network perspective on business models (Palo and Tähtinen, 2013; Bankvall et al., 2017; Spieth et al., 2019), emphasizing that network relationships constitute one of a firm's most crucial resources (Håkansson and Snehota, 1989). From this perspective, markets are characterized by complex and heterogeneous exchanges where interactions between actors are important arenas for managing relationships (Spieth et al., 2021). Consequently, from this perspective, the main purpose of the focal firm, understood as an actor embedded in a network, shifts away from the classical notions of efficient allocation and structuration of internal resources (Johanson and Mattsson, 1987) to that of linking and relating the firm's activities and resources to the activities and resources of other actors in the network (Håkansson et al., 2009). Consequently, the interplay between network level interactions and firm level business models emerges as the key focus of attention for understanding business model innovation in networks (Bankvall et al., 2017; Spieth et al., 2021). In addition, while business model innovation plays out on both firm and network levels in parallel, actors also develop established and new relationships in the industrial network so as to be able to (re)act on new business opportunities (Palo and Tähtinen, 2013).

2.4. Synthesis and research gap

Sustainability transitions literature argues that new technology is adapted through a combination of external pressures for change and the presence of potentially alternative technologies (e.g., Geels and Schot, 2007). A key for such a transition lies in the process of simultaneous formation of new technology, new business models, and the creation of a market niche (Bidmon and Knab, 2018; Geels et al., 2016). However, from a business model innovation perspective, we know little about how incumbents organize for anticipated sustainability transitions. To address this, we build upon two main starting points. First, Doganova and Eyquem-Renault's (2009) observation that business models are not passive representations of how firms do business; they can also have an active function as "market devices" that, from the position of our paper, helps crafting a new market niche. Second, incumbents, rather than using only internal resources for changing a business model, can attempt to generate business model reconfiguration by drawing on contextual resources and competences in partnerships (Calia et al., 2007; Spieth et al., 2021).

Concepts like networked business models (Palo and Tähtinen, 2013) and business model innovation alliances (Spieth et al., 2021) are important for understanding how business model innovation plays out on firm and network levels in parallel. However, due to the systemic nature of sustainability transitions, such transition processes often challenge existing roles and network configurations (Geels and Schot, 2007), and require market shaping through interactions between various actors, both inside and outside existing industrial networks (e.g., Bankvall et al., 2017). Such transitions are primarily not about exploiting existing technologies in innovative ways (e.g., Palo and Tähtinen, 2013), but are driven by profound innovations that may have long term and disruptive effects on existing socio-technical systems. Consequently, in such transitions a future emerging network is not necessarily orchestrated by a strong focal actor, as depicted in, for example, Spieth et al., 2021 but could be co-created by a number of actors simultaneously.

3. Methodology

3.1. Research approach

This paper is the result of an abductive research process (Alvesson and Sköldberg, 2000; Dubois and Gadde, 2002, 2014), and uses three cases as illustrative examples (Berggren et al., 2015; Siggelkow, 2001, 2007). The three cases were subjects of initially independent studies with slightly different research designs and purposes. Our joint research journey began, however, while we were comparing experiences from these three case studies, which led to the serendipitous observation of a common pattern of incumbent firms trying to navigate some potential sustainability transitions. Through post hoc reflections the concept "experimental networks" crystallized to denote the observed phenomenon, which has so far, considering its potential significance as a means for business model innovation, gained limited scholarly attention.

In order to overcome the limitation posed by original research designs of the three case studies differing slightly, we then returned to the field and collected additional data to ensure comparability among the cases. In parallel, we analyzed the data iteratively and further developed the conceptualization of the experimental networks for business model innovation. Our journey was thus non-linear, continually going back and forth between empirical observations and theory (Dubois and Gadde, 2002). Such an intellectual journey was useful for identifying the characteristics of the phenomenon in question while bolstering the plausibility of our argument in a creative way (Dubois and Gadde, 2014; Siggelkow, 2007). Albeit the nonlinear nature of our journey, in retrospect we can identify three main stages; a first round of data collection in three independent case studies, post hoc reflections, and the collection of additional data and further crafting of the conceptualization.

3.2. The three cases and their inclusion rationale

The three cases were studies of pre-commercial projects in which emerging technologies challenged the established regime of fossil fuel in road transportation and heavy manufacturing industries. If successful, each of the technologies could potentially contribute to a transformation of the respective industry sector and, as a consequence, to disruptions of existing business models. The cases were as follows:

- *eHighway E16:* A demonstration project of electric road system (ERS) technology, in which long haul trucks were charged dynamically with electrical energy while transporting goods on a public highway. The ERS technology has the potential to decrease the pressure on the trucking industry to lower its CO_2 emissions caused by its use of fossil fuels.
- *Hybrit:* A visionary production process development project aiming to potentially replace coal with hydrogen in industrial steelmaking processes. This project, if successful, would be a key step in initiating a radical change in steel production, which at present is one of the major global industrial emitters of CO_2.
- *Autopilot*: A real life test of autonomous public bus operations on public streets. The autonomous bus technology has the potential to completely transform urban public transportation, which by tradition relies heavily on large human-driven buses operating on fixed routes and schedules.

Through comparison of the cases, we identified a common pattern of incumbent firms trying to navigate potential sustainability transitions. Further, we found that the cases shared additional common characteristics that made them suitable as illustrative examples. Firstly, the cases were all embedded in emergent and potentially systemic sustainability transitions of CO_2 intensive industries. Secondly, the cases all show early signs of leading toward redefinition of industrial boundaries. Thirdly, the cases all include a number of incumbent firms with limited histories of collaboration, but which, through these new collaborations, attempt to take leading roles in the emerging transitions. Lastly, in all three cases, the project members attempt to address business model challenges concerning potential transitions. Given these shared characteristics, the cases revealed a replication logic, that is, each case corroborated a common pattern, enabling us to compare both similarities and differences among the cases, and to craft a theoretical conceptualization (Ridder, 2017; Yin, 2014).

3.3. Data collection and analysis

In line with a qualitative case study approach, empirical data were collected using multiple methods (Eisenhardt, 1989; Yin, 2014; Barratt et al., 2011), see Table 1. The data were collected through semi-structured interviews in combination with document analyses and direct observations. In all cases, the interviews were conducted with

Table 1
Data collection methods.

Data collection method		Data characteristics		
		eHighway E16	Hybrit	Autopilot
Semi-structured interviews	Industrial companies	4 interviews (3 h)	4 interviews (5 h)	5 interviews (5 h)
	Governmental	2 interviews (2 h)	2 interviews (2 h)	1 interview (1 h)
	Other organizations	–	1 interview (2 h)	1 interview (1 h)
Document analyses	Reports	30+ short project reports (100+ pages) and 1 longer report (46 pages)	10+ reports from the organizations (500+ pages)	Government report on self-driving vehicles (900+ pages) 2 Annual reports (100+ pages)
	Presentations	30+ presentations (150+ slides)	3 presentations (46 slides)	10+ presentations (150+ slides)
	Websites	1 project website	1 project website	1 project website
	Press and media	20+ press releases	20+ press releases	10+ press releases
	Videos	30+ videos (2 h)	10+ videos (2 h)	10+ videos (2 h)
Direct observations	Site visits	1 visit (1 h)	2 visits (5 h)	1 visit (2 h)
	Meetings	4 meetings (24 h)	–	–
Other	Informal interactions	Multiple interactions in various contexts (e.g., meeting researchers with several years' experience of the project)	–	Multiple interactions in various contexts (e.g., during transportation forums and 'think tank' meetings)
	Public debates	2 public debates (2 h)	1 public debate (1 h)	–

representatives from industrial companies, governmental entities, nongovernmental organizations, and industrial trade associations. The studied documents included company and project reports, academic publications concerning the cases, project presentations, websites, press and media material, and promotional videos. In addition, in all cases, we interacted with project participants and external experts at various workshops, meetings, and research seminars, as well as following relevant public debates.

The interviews took part on several occasions during 2017–2018 (see Table 2 for details). Out of the total 20 conducted interviews, 17 were transcribed and three were captured with notes. During the interviews, we followed semi-structured interview guides, which gave us leeway to adjust, add, and change questions based on what we learned during the interviews. Since the three case studies were originally initiated independently, the respective interview guides were not identical. However, the topics of the upcoming sustainability transitions, technological development, roles, capabilities, and motives of the collaborating actors, as well as business and industry implications were covered for all three cases. Furthermore, after the post hoc reflections, we returned to the field to collect additional data with the updated interview guides. Thus, the topics we covered in the three case studies were well aligned and directly linked to the research aim (see Appendix A).

The interviews for the first case study (eHighway E16) were carried out from January to May 2018. Six interviews were held with nine respondents from five different organizations (some interviews involved more than one respondent), all of whom were intimately involved in the project. The interviews for the second case study (Hybrit) ran from May 2017 to June 2018. The interviews took place on seven occasions with nine respondents (again, some interviews involved more than one respondent) representing various organizations. The interviews for the third case study (Autopilot) were conducted between November 2017 and December 2018. Overall, the case study included seven interviews with respondents from five different organizations.

For the data analysis, we benefited from both the deductive and inductive nature of abductive research. On the one hand, the four domains of the service, technology, organization, and financial (STOF) model (Bouwman et al., 2008) were used as a guide to describe the potential business model implications in each case. The researcher responsible for a particular case returned to the collected data and wrote up the case descriptions, supported by quotes according to the STOF model (see section 4). On the other hand, the whole research team met frequently to interpret, compare, and discuss the empirical data in conjunction with the conceptualization of the identified phenomenon. While the former was more deductive than the latter, the data analysis process became nonlinear and experimental, in line with the qualitative research advocating close reading, writing and rewriting, and reflexive interpretation (Alvesson and Sköldberg, 2000; St. Pierre and Jackson, 2014). During this process, the findings were synthesized by iteratively reading, listening, and extracting illustrative quotes while simultaneously applying the focal framework from theory and with the emerging conceptualization from observations in mind (see also Berggren and Karabag, 2019; Siggelkow, 2001).

3.4. *Research quality*

In terms of research quality, we recognize Dubois and Gadde's (2014, p. 1282) two key criteria for building quality in case study research: "the description of the methodological procedures'' and "the presentation of the case study and its relation to theoretical concepts''. We address the former by presenting our specific methodological journey in detail. As we explain above, rather than being linear, the journey was reflexive and iterative. In terms of the second criterion, we attempted to match the theory with the empirical findings in an iterative fashion and present the rich insights in a parsimonious fashion. Two processes characterized our matching of theory with empirics. First, we continuously collected and re-analyzed data; visited and revisited the literature, and, in parallel, crystallized and re-crystallized the concept of experimental networks. During this process, we triangulated data with different types (e.g., interviews vs. written documents) and practiced peer debriefing (e.g., at several international conferences) to cover complementary views and be able to redirect the study when needed. Second, we – the coauthors – engaged in many hours of discussion, complementing and challenging each other's ways of interpreting data and theory. By doing so, we acknowledged the trap of one-sided focus on data (e.g., overconfidence in data analysis techniques), and thus developed a more reflexive and self-critical approach (Alvesson and Sköldberg, 2000).

Nevertheless, our study has obvious methodological limitations. All our cases are, for instance, embedded in Sweden, a contextual characteristic which may have influenced how the cases unfolded in practice. Furthermore, our sample is narrow and we had slightly different modes of access to data in the cases. However, in this nascent stage of research we do not consider this a problem (Edmondson and McManus, 2007). Since our purpose has been to conceptualize an empirical phenomenon and thereby contribute to the building of new theory (Eisenhardt, 2021), rather than verifying or falsifying already established concepts, we are not claiming that our findings are universal nor that they reveal statistically significant relationships. Instead, we explicate and describe a phenomenon of significance that was common to our three cases, and it

Table 2
Semi-structured interviews.

	Interviewee position/role	Company	Occasion	Duration and type of memo
eHighway E16	Consultant	Region Gävleborg (County Council)	January 26, 2018 Face to face, Stockholm	60 min Detailed notes and recording
	Strategist	Region Gävleborg (County Council)	February 13, 2018 Face to face, Gävle	70 min Detailed notes and recording
	Project Manager for Electric and Hybrid Powertrain Technology	Scania (Truck manufacturer)	February 14, 2018 Face to face, Södertälje	50 min Detailed notes and recording
	Electricity Grid Manager and Engineer	Sandviken Energi (Electric utility)	February 15, 2018 Face to face, Sandviken	50 min Detailed notes and recording
	CEO	Ernst Express (Haulage company)	February 15, 2018 Face to face, Avesta	40 min Detailed notes and recording
	Joint interview: Head of eMobility Nordic and two Business Developers at eMobility Nordic	Siemens (Electrical equipment manufacturer)	February 16, 2018 Face to face, Solna	55 min Detailed notes and recording
Hybrit	Head of Sustainable Industry Unit	Swedish Energy Agency (Governmental agency)	May 17, 2017, Face to face, Eskilstuna	70 min Detailed notes and recording
	Energy and Environment Director	Jernkontoret (Swedish steel producers' association)	May 7, 2017, Face to face, Stockholm	110 min, Detailed notes and recording
	Executive Vice President and Chief Technology Officer	SSAB HQ (Steel producer)	November 24, 2017, Face to face, Stockholm	80 min, Detailed notes and recording
	A member of Swedish Parliament	Sveriges Riksdag (Swedish parliament)	November 16, 2017, face to face, Stockholm	40 min, Detailed notes and recording
	Joint interview: R&D Manager, Environmental Manager, and a Technical Expert	SSAB Europe, Luleå (Steel producer)	December 6, 2017, Face to face, Luleå	130 min, Notes
	Managing Director	Hybrit (Joint venture)	May 23, 2018, Digital	65 min, Detailed notes and recording
	Head of Industry Decarbonization R&D Portfolio	Vattenfall (Electric utility)	June 8, 2018, Digital	70 min, Detailed notes and recording
Autopilot	Project Manager	Nobina (Bus operator)	November 29, 2018, Face to face, Stockholm	90 min Detailed notes and recording
	Business Manager	Nobina (Bus operator)	December 19, 2018, Face to face, Stockholm	55 min Detailed notes and recording
	Project Manager at Traffic Office	Stockholm City (City council)	December 4, 2018, Face to face, Stockholm	70 min, Detailed notes and recording
	Head of Program	Ericsson (Telecom systems manufacturer)	June 11, 2018, Face to face, Stockholm	45 min, notes
	Project Coordinator	Integrated Transport Research Lab, KTH Royal Institute of Technology (University)	April 20, 2018, Face to face, Stockholm	45 min, notes
	Business Development Manager	Scania (Transportation solutions)	March 15, 2018, Face to face Stockholm	60 min, Detailed notes and recording
	Joint interview: Head of Business Development and Business Development Manager	Scania (Transportation solutions)	December 15, 2017, Face to face, Stockholm	60 min, Detailed notes and recording

is plausible to expect that there are similar features also in many other endeavors of business model innovation. However, testing the transferability of the experimental network concept on other cases and contexts is an issue for future research (Edmondson and McManus, 2007).

4. The cases

The paper is based on findings from studies of three pre-commercial projects which were executed in Sweden during the late 2010s. In spite of being initiated independently of each other, the projects constituted different industrial attempts to fulfill the national CO_2 reduction agenda of Sweden. All three projects encompassed a number of firms, which collaborated in novel constellations across traditional industrial boundaries. They were all characterized by a high level of uncertainty in terms of technology outcomes, industrial development, and potential business model implications. The projects were partly financed by the companies engaged, and partly with grants from various national state agencies. Table 3 provides an overview of the three cases.

In the following text, each of the projects is described according to the STOF model (Bouwman et al., 2008). Thereafter, in section 5, the findings from the case comparisons and analyses are reported.

4.1. Case one: eHighway E16

eHighway E16 was a demonstration project where an electric road systems (ERS) technology was installed and operated on a public freeway. The project was executed from 2016 to 2020 under the coordination of the regional County Council of Gävleborg, approximately 200 km north of Stockholm, Sweden. The project was a result of a pre-commercial public procurement by the Swedish Transport Administration and was partially financed by the Swedish state. Indeed, eHighway E16 was one of the world's first real tests of using ERS for haulage transports on a public road.

The road transportation sector is one of the most significant sources of CO_2 emissions, and heavy road freight transport represents one third of these emissions. The basic idea of ERS is to offer dynamic electric charging of vehicles while they are in motion, driving on a road. This enables smaller and lighter batteries than those used in static charging and may potentially lead to CO_2-emission free transportation in the future. Currently, there are several competing ERS technologies under development, typically based on conductive charging from overhead catenary lines, or conductive or inductive charging systems built into the road (Wang et al., 2019). Thus far, however, there are no commercial ERS applications in operation in the world.

In the eHighway E16 project, the truck manufacturing company Scania and the electrical equipment manufacturer Siemens were responsible for providing the ERS technology. During the project's execution, there was a 2-km electrified stretch on a public freeway where two trucks in regular operations dynamically charged their batteries. The two trucks, transporting goods between various industrial plants in the inland and a seaport at the Baltic coast, were operated by a local haulage firm called Ernsts Express.

Table 3
Case descriptions.

	eHighway E16	Hybrit	Autopilot
Industry	Heavy road freight transport	Steel production	Public transport
Technology	Electric road system (ERS), i.e., dynamic electric charging of vehicles	Hydrogen-based direct reduction process	Autonomous bus
Duration	2016–2020	2016–2035	2015–2018
Scope	To demonstrate the conductive ERS technology on a public road.	To design and build an operational pilot plant.	To demonstrate self-driving buses on a public road.
Content	Installation, operation, and verification of conductive charging from overhead catenary lines.	Planning, demonstrating and implementing technologies for hydrogen-based steel production.	Bus operations and traffic management, including testing of technologies and customer interfaces.
Primary participants	Ernsts Express (Haulage company); Region Gävleborg (County council); Scania (Truck manufacturer); Siemens (Electrical equipment manufacturer)	LKAB (Mining company); SSAB (Steel producer); Vattenfall (Electric utility).	Ericsson (Telecom systems manufacturer); ICT Urban Arena (Project facilitator); Klövern (Real estate company); KTH Royal Institute of Technology (University); Nobina (Bus operator); SJ (Railway company); Stockholm City (City council).

4.1.1. Service domain

In order to provide a more environmentally sustainable transport sector, ERS is a potential solution to the challenge of electrifying long haul, heavy duty road transportation. However, a general shift to ERS technology in trucking would radically change the rules of the game for both road freight transports and the truck manufacturing industry. As one of the interviewees explained:

“We need to eliminate all CO_2 emissions. There are two main pathways. Alternative one is that we go for biofuels and end up with some emissions. Alternative two is that we go for electrification with batteries or continuous charging. Batteries work well for trucks going 50 km but become too big and heavy for operations between 500 and 1000 km. Continuous charging is at present the only solution for heavy road freight going 100, 200, or 300 km stretches.” (Project manager, Scania).

For the regional County Council, the project aligned well with the ambition to promote regional development, enhance the brand as a thriving industrial region, and contribute to regional industrial growth. For the truck manufacturer Scania, the project offered an opportunity to test an innovative hybrid electric truck technology adapted to ERS operations and thus take the lead in a potential technology shift from diesel propulsion to ERS. For the electrical equipment manufacturer Siemens, the project created an opportunity to expand into the market for heavy road freight transports, and to challenge the traditional roles and logic of the entire industry by adapting two well established applications based on equipment for railways (the conductive overhead line and the current collector) to heavy duty trucking. Furthermore, ERS has a potential to enable haulage firms to offer environmentally friendly heavy road freight transports, which aligned with Ernsts Express’ brand as a “sustainable” and “green” haulage company, while at the same time incurring lower operating costs for fuel (electricity instead of diesel).

4.1.2. Technological domain

For the project, a conductive overhead line was installed on 2 km of public highway, which meant that physical charging infrastructure was added to the existing road network. Electricity was transmitted from the overhead lines to the two hybrid electric trucks through current collectors installed on the roofs of the truck cabins. Since this is an evident deviation from the dominant propulsion technology of internal combustion engines, it meant that Scania had to develop significant competence in the fields of hybrid electric power train technology and dynamic charging. If implemented in the truck market on a full-scale basis in the future, it might have profound effects on Scania’s businesses. Electric powertrains are cheap commodities compared to internal combustion engines, and such a shift would challenge Scania’s traditional core competences, as well as result in significant changes in the highly profitable aftermarket of maintenance services and spare parts. For Siemens, however, the ERS technology only constituted minor adjustments of an established electrical equipment technology in order to install the electric infrastructure on the road as well as to equip the trucks to enable dynamic electrical charging. The following quote reflects how the ERS technology in itself was not perceived as a major challenge by Siemens:

“What is the problem? Everyone says business models. Maybe that is an acknowledgement that the [ERS] technology is so mature that we cannot speak about it as the problem anymore.” (Head of eMobility Nordic, Siemens).

4.1.3. Organizational domain

All in all, there were 36 official stakeholders in the eHighway E16 project. Among these, only the County Council, Scania, Siemens, and the financing agencies were originally acknowledged as core members on the project website.[1] The wide range of actors was coordinated by the County Council, which mainly focused on marketing the project and gaining support from various policy actors. The other core actors collaborated with different members in the project for more specific purposes. For instance, for the installation of the electrical infrastructure, Siemens worked in close collaboration with the electric utility that owned the regional power grid, as well as with the road administration that operated the road. Furthermore, there was close collaboration between Siemens and Scania to create a seamless physical and digital interface when installing the current collectors and electrical equipment in the trucks.

4.1.4. Financial domain

If ERS is to break through on the commercial market in the future, it would potentially lead to dramatically reduced fuel costs, one of the most significant operating costs in heavy road freight transport. For the local haulage firm, Ernsts Express, which already ran its trucks on 100% biodiesel, the incentive was therefore strong to engage in eHighway E16 to both decrease fuel costs and maintain its position as the regional choice for green heavy road freight transport in the premium price segment. For Scania, the project offered an opportunity to gain a leading position in the technology shift to electrification and to retain its premium market position. For Siemens the project opened an opportunity to increase sales volumes by creating a new market for electrical knowhow and electrical equipment. For the County Council, the project was well aligned with increasing the business activities in the region and thus contributing to regional industrial growth in both short and long term.

[1] During the operations, Ernsts Express also was acknowledged as one of the most important actors of the project.

4.2. Case 2: Hybrit

Hybrit is an ongoing visionary innovation project aimed at developing a hydrogen based, direct reduction process technology for steel production. If the project succeeds, coal in steelmaking will be replaced by hydrogen, thus providing a significant step toward more sustainable production. The project was created as a response to the pressing demand to take action in order to fulfill the national environmental policy for reaching zero CO_2 emissions in the iron and steel industry before 2045.

At present, the global iron and steelmaking industry is a significant polluter, producing a major share of the industrial CO_2 emissions in the world (IEA, 2019). In Sweden, one of the most important steel producing countries in Europe, the major steel company SSAB is known for having one of the world's most CO_2 efficient steel production systems. Even so, SSAB is the single largest emitter of CO_2 in the country, representing approximately one tenth of the total national CO_2 emissions. Consequently, Hybrit is an ambitious attempt to make steelmaking more sustainable.

The project is run by three main actors: the steel company SSAB, the mining company LKAB, and the electric utility Vattenfall. It encompasses three stages; feasibility studies (2016–2017; completed), construction and operation of pilot plants (2018–2024; ongoing), and demonstration plants (2025–2035; planned). After 2035, the technological know-how is expected to be sufficiently mature for the Hybrit technology to be deployed in commercial operations.

4.2.1. Service domain

In offering fossil-free high-performance steel, the Hybrit technology is currently perceived as the best technological option for implementation so as to fulfill the national objectives of 2045. No other emerging steel producing technology promises to eliminate CO_2 emissions to the same degree (Karakaya et al., 2018). One of the interviewees explained how the technology will eliminate the emissions:

"The steelmaking process that we are using today is the single largest emitter of CO_2. [However,] Sweden uses in principle almost no fossil fuels in electricity generation and has significant excess electricity generation, exporting around 20 TW h of very clean electricity every year. At the same time, SSAB is importing quite significant amounts of coal to run blast furnaces. If we could develop a process utilizing electricity instead of coal as the energy source, then we would avoid the CO_2 emissions."

Thus, if the project succeeds, SSAB, with the support of LKAB and Vattenfall, will be able to offer environmental value with fossil-free steel — a service both to society and to its customers. In addition, the mining company LKAB will be able to supply fossil-free iron ore pellets to SSAB and continue to contribute to local economic development in Sweden's arctic region. Moreover, Vattenfall, by gaining new competences, will be able to offer fossil-free hydrogen based on renewable energy sources.

4.2.2. Technological domain

The project constitutes a radical process innovation which will probably have a far-reaching impact on the entire steel industry worldwide. If the project succeeds, the Hybrit technology will replace the current production processes in SSAB's blast furnaces, which account for two thirds of the steel production in Sweden. In doing so, Hybrit technology will use hydrogen instead of coal as the reducing agent and, consequently, CO_2 emissions will be replaced by water as byproduct. Vattenfall will provide fossil-free electricity (primarily from wind power) for the large-scale hydrogen production by electrolysis of water, while LKAB will start producing fossil-free iron ore pellets. Consequently, if the technology were to be introduced on a full-scale basis in the future, many of the core technical competences in ironmaking and steel production will change dramatically.

4.2.3. Organizational domain

In total, Hybrit engages three core partners. The project is executed by a joint venture company, Hybrit Development, established in 2017, which is equally owned by SSAB, LKAB and Vattenfall. In addition, the project collaborates with a number of universities and research institutes that address different technical, economic, and societal aspects of the transition. The feasibility and pilot phases are partly funded by the Swedish Energy Agency. As one of the interviewees explains, the three companies cover an important part of the future value chain of hydrogen-based ironmaking:

"As three companies, we cover the value chain: from the mine to specialized steel products, and from primary energy supply in the hydropower dams and wind power plants all the way to the hydrogen supply. If you are faced with disruptive changes and if you try to do something alone, you can only cover a limited part of the value chain. You are more vulnerable if you do things alone. The way we have done now, places us really in the same boat."

4.2.4. Financial domain

The technology will potentially enable SSAB to transition from being one of the world's most CO_2 efficient steel producers into a global market leader in fossil-free high-performance steel, thus strengthening its position in the premium market segment. Even though the Hybrit technology may result in price increases for the steel produced (due to the high costs of electricity and hydrogen), the customers are likely to be willing to pay higher prices to buy fossil-free steel due to projected changes in European environmental legislation, as well as anticipated price increases within EU's Emissions Trading System. Thus, the Hybrit project is expected to change both SSAB's revenue model and its value capture base.

The potential implications for Vattenfall and LKAB may vary. If the Hybrit project succeeds, the energy company Vattenfall will extend its business to the hydrogen production market and strengthen its core energy supply business. The mining company LKAB, on the other hand, will secure, and even increase, the demand for its iron ore, since if the technology breaks through, fossil-free, iron-ore based steelmaking would gain momentum and become superior to scrap based steelmaking (which does not require iron) in terms of environmental impact. Thus, for LKAB and Vattenfall, the Hybrit hydrogen technology primarily enhances existing revenue models with the potential of stable (or even increased) future sales volumes. The exact long-term effects are unclear, but if the Hybrit project succeeds, it is expected to disrupt the industry at both national and global levels. In addition, since they are equal owners of the intellectual property rights via the joint venture, all three companies would also benefit from technology transfer to other countries.

4.3. Case 3: The Autopilot

The Autopilot was the first real life test of a driverless bus on a public street in Scandinavia, and the first in the world using a 5G network for autonomous driving. During 2018, two autonomous buses ran at a speed of 20 km/h along a 1.5-km route in one of the premier industrial science parks in the outskirts of Stockholm. The project was a result of development in automotive and telecommunication technologies, but it was also triggered by the national environmental agenda to reach fossil-free road transportation by 2030.

The integrated application of the novel technologies in question risked being highly disruptive for the transportation industry. If implemented on a full-scale basis, the autonomous buses are projected to have profound implications for public transportation, altering traditional structures and roles, and a completely new division of industrial labor might emerge in the future. Whether or not this will come to pass remains however unclear.

4.3.1. Service domain

Autopilot constituted a step toward a more sustainable last mile solution in public transportation, which in the long run could become a tough competitor to private cars. The bus operating company Nobina was one of the project's key actors, since autonomous vehicles might have major implications for the service. Bus driver salaries represent a significant portion of the operating costs of bus operations today, and thus autonomous buses might lead to drastic cost reductions. Further, autonomous vehicles enable a radical renewal of public bus services, with smaller vehicles, bus operations on a larger number of routes, and increased route flexibility, i.e., offering new value propositions to the customers. In addition, autonomous buses might in the long run lead to an introduction of "on demand" public transportation services. Thus, the demarcation line between bus services and taxi services might in the future become blurred or even disappear.

Other stakeholders also had significant interests in the project. For the telecom company Ericsson, the project was an opportunity to offer telecommunication services to the transportation sector, thus extending its value proposition to a new customer base. For the real estate company Klövern, owning the premises of the industrial park, it was an opportunity to include a unique shuttle service as part of their real estate service offerings, making their premises in the industrial park more attractive to existing and potential tenants, as well as (in the long run) reducing parking space. For the railway company SJ, the project was an opportunity to offer more integrated, intermodal, transport services. And for Stockholm City, it was an opportunity to reach its sustainability goals and strengthen its image as an innovative and thriving business region.

4.3.2. Technological domain

A number of technological advances in sensors, telecom networks, internet of things, artificial intelligence, batteries, etc., had enabled autonomous buses as a potentially new way of organizing public transportation. The main difference compared with the traditional way of organizing public transportation is substituting the driver with advanced technologies as the vehicles use GPS, sensors, software algorithms, etc., to ensure that they stay on track. As stated in a press release from the telecommunications company Ericsson about the Autopilot project:

"[our] platform serves as the virtual bus driver for the shuttles in Stockholm, communicating with smart, sensor enabled bus stops, traffic lights, and road infrastructure."

In addition, technological development in the telecom networks and cloud services had enabled a transition toward scaled up and faster data sharing between the vehicles and supporting infrastructure:

"[5G network] provides completely new opportunities for [transport since] you can assign and guarantee broadband, higher capacity, and lower response times."

(presentation by an expert on Intelligent Transport Systems, Ericsson).

If implemented on a full-scale basis, the tested technology could potentially address environmental challenges by using small autonomous buses as an attractive last mile solution that, in the long run, could reduce the usage of private cars as the dominant means of transportation and consequently contribute to the goal of significantly decreased CO_2 emissions.

4.3.3. Organizational domain

All in all, the Autopilot project had seven core partners. It was executed under a multi-partner program, bringing together private firms, academia, and government agencies to develop, test, and evaluate new ideas and technologies for more sustainable transportation. The project, which combined product and systems innovation, received partial financial support from the Swedish Governmental Agency for Innovation.

The largest bus operator in the Nordic countries (Nobina) was the principal actor in the project. Other major actors included the telecom company Ericsson, Stockholm City, and the real estate company Klövern that owns major properties in the industrial park where the buses were operating. All actors contributed their unique competences; Nobina provided the competence of running buses, Ericsson contributed its competences in 5G networking, cloud services, and sensors, the City of Stockholm covered public administration and the regulatory environment, Klövern was responsible for property management and providing a garage, SJ ensured the integration of the transportation service with its commuter train services, ICT Urban Arena facilitated the project, and KTH Royal Institute of Technology evaluated the project from behavioral and systemic perspectives.

4.3.4. Financial domain

While self-driving vehicles are a technological innovation per se, the most radical potential business model effects are, nevertheless, within bus operations. A successful solution to the "last mile" problem of public transportation is expected to reduce the use of private cars, and consequently, increase the use of public transport. This benefits Nobina and SJ, while also cutting the payroll costs of the bus operator. In the long run, with no salary costs for bus drivers, buses could be reduced in size and bus services could be more frequent and flexible than at present. In turn, the telecom company Ericsson would gain access to a new customer base in the transportation sector by providing a suite of solutions and services that substitute the driver. Finally, real estate companies (e.g., Klövern) and municipalities (e.g., Stockholm City) can financially benefit from freeing up space devoted to parking lots for private cars while providing better services and maintaining an attractive brand image for their tenants and citizens.

5. Analysis

5.1. Incumbents' engagement in networks for business model innovation

The three cases demonstrate how several incumbent companies, in anticipation of upcoming sustainability transitions, engaged in networks with other actors to explore opportunities for business model innovation. Table 4 summarizes the intentions behind each key actor's network engagement, as well as potential business model implications of this engagement. As seen in the table, each of the collaborations pushed the limits of the established businesses for a number of actors and had the potential to result in an array of novel, re-configured, or adjusted business models.

In each of the cases, a group of companies gathered around a visionary idea for potential future value propositions. However, for each of the involved companies the project in focus constituted an attempt to claim a position in a conceivable future business context, while at the same time attempting to shape this nascent context in line with the company's interests. For instance, by introducing novel attributes to the service domain, the three companies Scania, SSAB, and Nobina explored value offerings outside of the existing businesses, while the rest of the companies either tried to extend existing offerings into new markets and applications, or to enhance an already strong position on an existing market. In the technology domain, the offerings implied exploration of new technological know-how for approximately half of the companies, while the rest of the companies could draw on, or make minor adjustments to, their already existing technologies. The technological exploration was especially evident for Scania, SSAB, and Nobina, whose core competences were directly affected by the respective projects. Furthermore, in the organizational domain, the offerings implied novel constellations of potential future partnerships, challenging traditional industrial boundaries, for example between the industries of automotive (Scania) and electrical equipment (Siemens), steel production (SSAB) and renewable energy (Vattenfall), and bus transports (Nobina) and telecom (Ericsson). Finally, the implications in the financial domain were on the other hand rather straightforward for all the companies, with monetization in line with already established revenue models. If successful, the three projects might in the long run potentially result in

Table 4
Potential business model implications for different actors.

		Intention to create	Service Domain	Technological Domain	Organizational Domain	Financial Domain
eHighway e16	Scania	Take the lead in a potential technology shift from diesel propulsion to ERS	New offering:Zero-emission hybrid-electric trucks	New competence in the fields of hybrid-electric power train technology and dynamic charging	Close collaboration with electrical equipment manufacturer	Retain premium market position and sustain sales
	Siemens	Expand into the market for heavy road freight transports	Extended offering: Adapting applications based on equipment for railways to heavy-duty trucking	Adjustments of an established electrical equipment technology	Close collaborations with truck manufacturer, electric utility, road administration etc.	Increase sales volumes
	Region Gävleborg	Promote regional development	Enhanced offering: A thriving industrial region	No major effects	No major effects	Contribute to regional industrial growth
	Ernsts Express	Offer environmentally friendly heavy road freight transports at lower operating costs	Enhanced offering: A "sustainable" and "green" haulage company	No major effects	No major effects	Decrease fuel costs and maintain position in the premium price segment
Hybrit	SSAB	Develop and take the lead in fossil-free steelmaking	New offering:Fossil-free high-performance steel	New hydrogen-based direct reduction process for steel production	Close collaboration with electric utility	Enhance the revenue in the premium market segment
	LKAB	Production of fossil-free iron ore pellets	New offering: Supply of fossil-free iron ore pellets	New way of producing fossil-free iron ore pellets	No major effects	Retain or increase sales volumes
	Vattenfall	Contribute to fossil-free hydrogen production	Extended offering: Supply of hydrogen based on fossil-free electricity	New competences in large-scale hydrogen production and storage	Close collaboration with steel producer	Increase sales volumes
Autopilot	Nobina	Radical renewal of public bus services with small autonomous buses and flexible routing	New offering: Flexible public transport on demand	Substituting the driver with advanced technology	Close collaboration with telecom systems manufacturer	Increase sales volumes and eliminate salary costs for bus drivers
	Ericsson	Offer telecom services to the transportation sector	Extended offering: Telecom services for new customer base	New application of technology for platform to serve as virtual bus driver	Close collaboration with bus operator	Increase sales volumes
	SJ	Offer more integrated, inter-modal, transport services	Enhanced offering: Integrate other modes of transport with existing railway services	No major effects	Collaboration with bus operator	Increase sales volumes
	Klövern	Make premises in the industrial park more attractive to existing and potential tenants	Enhanced offering: Including shuttle service for real estate tenants	No major effects	No major effects	Enhance market position and increase sales volumes
	Stockholm City	Enhance sustainability and promote regional development	Enhanced offering: Strengthen image as an innovative and thriving business region	No major effects	No major effects	Free up space and increase attractiveness of the city

retained or increased sales volumes on existing markets (e.g., Scania, Ernsts Express, SSAB, LKAB, and Nobina) and entries into new markets (e.g., Siemens, Vattenfall, and Ericsson), as well as significant reductions in operational costs (e.g., Ernsts Express and Nobina).

In all cases, the ambitious national sustainability targets were incompatible with "business as usual" for the incumbent firms and required new business models incorporating sustainability to a bigger extent than previously. However, the technological solutions were outside the reach of the firms' current service offerings, which necessitated broad collaborations and cross industry responses. Thus, while the implications for various actors were different, participation in the networks enabled a similar set of benefits, which were not available to the actors, neither individually nor through dyadic alliances.

While some of these benefits were mainly related to sustaining or enhancing current business models, others involved more future oriented positioning strategies beyond the anticipated transition (for typical quotes, see Table 5). Due to the nature of systemic innovation, the incumbent firms in all three cases lacked the internal competences required to create and offer radically enhanced value to their customers. Thus, the firms sought access to these competences across industrial boundaries. For example, the truck manufacturer Scania did not possess necessary competences in electric charging and propulsion that enabled offering a complete ERS solution. Instead, Siemens provided the competence on electrical equipment, and there was a tight interaction between the two companies when designing and implementing the solutions. Similarly, in the Hybrit case, Vattenfall offered the steel producer SSAB knowhow related to hydrogen as a source of renewable energy, and in the Autopilot project, the bus operator Nobina gained access to the telecom company Ericsson's key technologies and services that enable autonomous driving, such as 5G networks, cloud services, and sensors.

Furthermore, all three projects were executed in the context of significant uncertainties about both the potential sustainability transformations and the future roles of the actors involved. Consequently, the three projects served as testbeds for learning new technologies and new ways of doing business. For example, the participants in the Autopilot were not certain whether autonomous small buses merely represented a last mile solution as an extra service for travelers, or if they constituted a radical shift to a whole new transportation system based on dynamic bus routes. In the face of such uncertainty, simply combining complementary resources and competences was not sufficient in order to develop new business models. Thus, the learning benefits of participating in the networks had various facets: it allowed the actors to obtain insights from other actors into necessary technologies outside their fields of competence, and it allowed the actors to test their own new technologies on a small scale, without committing large amounts of money.

In addition, the configuration of the collaborations enabled the companies to pool resources, such as financial assets and personnel, in order to maximize the likelihood of achieving business model innovation, while simultaneously keeping their established businesses running. By doing so, the companies pushed the boundaries of their operations, as well as shared the risks in their individual attempts to innovate their

Table 5
Typical interview statements on the benefits of the cross industrial collaboration.

	eHighway E16	Hybrit	Autopilot
Access to complementary competences	"Our trucks are like any hybrid truck we offer when they do not drive on the ERS. To operate on the ERS, however, the current collectors need to be there. We can operate the current collectors, but we need the electrical equipment manufacturer to supply them first." (Project Manager, Scania)	"If we convert the whole Swedish steel industry [with Hybrit], it will consume 10% percent of electricity production in Sweden. It would be unrealistic, not to cooperate with Vattenfall […]" (Head of R&D portfolio, Vattenfall) "We (three companies) have of course very extensive knowledge if you think about the value chain of the future [hydrogen-based] iron and steel production […] We, as three companies, are having leading technologies within the respective field. So, we make a [good] combination" (Vice President, SSAB)	"But for the vehicles … to be self-driving, it is required that the vehicles can keep track of each other, and we of them. It will be supported by cloud solutions with data-sharing and analysis tools and with a 5G network - which Ericsson aims to become a world leader in." (Presentation at the Almedalen forum, Ericsson) "ICT Urban Arena was a facilitator to perform tests in the area … Klövern had estates close by and also the garage … you need a vehicle you need an operator [Nobina] with the relevant permissions … to do some 5G tests you have Ericsson" (Project manager, Stockholm City)
Test-beds for learning	"Initially we thought that ERS would be installed on the entire stretch of road between point A and B. Now [after a period of operations], we are considering skipping downward slopes and only installing ERS on upward slopes." (Consultant, County Council) "Whenever our two truck drivers operate the trucks in commercial operations on the ERS, the electrical equipment manufacturer is present. Both parties gather experience and can assess how the technology is affected." (CEO, Ernsts Express)	"[…] if blast furnace in Lulea would be converted to hydrogen-based, it would mean 700–800 MW electric power. Given that the global market for hydrogen electrolysis today is at the range of 100 MW: nobody today has experience of electrolysis at 700–800 MW" (Head of R&D portfolio, Vattenfall) "What would we want to do with the Hybrit project is to develop an industrial process and test the various technologies in different parts, sometimes very much in detail to solve certain issue, and scale it up. That is what we want to do. Somebody needs to do that because otherwise this will never be tried. Otherwise, you will never know if it will fail or not." (Vice President, SSAB)	"Autopilot was kind of a technical pilot. We wanted to test the technical abilities of the buses … We learned a lot about the technical challenges." (Business manager, Nobina) "At first we didn't know what was to come … we have to learn from the actors that have this knowledge and have this product. If their products are implemented on the streets, how is the city affected?" (Project manager, Stockholm City)
Resource pooling and risk sharing	"There has been an extensive burden put on a lot of people. The money from the Transport Administration worked as a lubricant, but most of the financing is in-kind from the truck manufacturer, the electrical equipment manufacturer, and other stakeholders." (Strategist, County Council)	"If you are up to for disruptive changes and if you are alone, you can only cover a limited part of the value chain. You are also more vulnerable if you do things alone or loosely coupled" (Head of R&D portfolio, Vattenfall) "The industrial transition stages and associated technological and economic effects represent considerable risks and costs for the companies involved" (Feasibility study report, Hybrit)	"[Such projects] are expensive; a lot of money goes into them. Because when we start doing operations, the volume gets so large so fast. … And it is not possible for us to invest alone; we need the partners to make it possible." (Business manager, Nobina)
Leveraging external support	"The ERS project […] is a collaboration between the Swedish Transport Administration, the Swedish Energy Agency, and the Swedish Innovation Agency, which together with industry and academia will demonstrate and evaluate ERS as a possible method to decrease the use of fossil fuels in the Swedish transport industry." (Press release, Scania)	"It's important to note that the companies drive this. […] they are really ambitious and this is an ambitious project […]. There is a general societal discussion and the politicians' targets – which also help as driving forces. They [the companies] could not do this without financial help because [Hybrit] will be extremely expensive. So now they get financing for the research and, in the future, they will also need support for perhaps scaling up." (Energy and Environment Director, Jernkontoret) "The project has a momentum and trustworthiness; also, in terms of relations with the state, the government and authorities. It would be totally different [in comparison with if we were alone]. It [the collaboration] is a security for public funding and it gives the initiative a lot of trust if you have a plan to cover a large part of the value chain." (Head of R&D portfolio, Vattenfall)	"It wouldn't be possible for the Autopilot to drive there without involving the City […] we do like that our streets are used for innovative tests.“ (Project manager, Stockholm City) "We cannot do it alone, because public transport is financed by the public." (Business manager, Nobina)
Claiming space in a future transition	"Decarbonization of heavy road freight transport has been identified as a particularly difficult issue to address in the strive toward the Paris agreement. I absolutely believe in ERS: there is no other solution to decarbonize heavy road freight transport that is also financially sound." (Head of eMobility Nordic, Siemens)	"Now you see more and more steel and ironmaking companies talking about hydrogen as an obvious solution. So already now I would say that we have had an impact globally on defining the solution for the steel industry." (Video on website, Hybrit) "[…] the importance of sustainability and climate change will maintain and it will grow only stronger. Being on its forefront is a competitive edge. […] Our assumption is that external costs of fossil fuels will be internalized with renewable electricity – also because of the EU Emissions Trade System." (Head of R&D portfolio, Vattenfall)	"Autumn 2018 was a milestone. This marked the beginning of our regular services with autonomous buses in [another] district of Stockholm.“ (Annual report 2018, Nobina) "As connected and self-driving vehicles start to transform transportation, Ericsson's platform makes it easier … to become a successful example of the future of public transportation." (Press release, Ericsson) "It was [successful] because I think that it was the first step … now Nobina operates three self-driving buses in regular traffic in [another district of Stockholm]. So now, it is implemented. It will scale up." (Project manager, Stockholm City)

respective business models. By forming the collaborations, the actors also created a strong and unified voice, which increased the likelihood for each project to attract external support and be able to tap into public funding. In all three cases, the projects were publicly portrayed in the media as collective attempts to achieve necessary sustainability transitions. In addition to financial support from the state, the three networks were also backed by industry associations, research institutes, and other nongovernmental organizations.

Last but not least, common to all cases was that they were future oriented and addressed business conditions that may result from potential technological shifts in the future. Thus, the key actors and their partners enhanced their competences in advance of the anticipated sustainability transitions via real life tests. By doing so, the project actors not only responded to perceived pressures and demands for change in the form of a sustainability transition, but also proactively claimed spaces in their respective value networks, long before any commercial breakthrough of ERS, fossil-free steelmaking, or self-driving public buses.

5.2. Network characteristics

Even if the size, scope, technology, and number of participants were different in all the three cases, the collaborations were based on the need for a sustainability transition away from fossil fuel to more environmentally friendly technologies, which challenged established industrial structures and divisions of labor. Further, each of the initiatives belonged to an early, explorative phase of a potentially emerging radical transformation, and they were all driven by strong perceived needs among the involved organizations to collaborate in order to test and learn about emerging technologies and probe circumstances that could lead to profound systemic effects.

Thus, the three cases exemplified how groups of established companies from different industries, in parallel to their everyday operations formed time-limited networks in order to explore alternative technologies and to simulate possible configurations for future business models. Consequently, the cases exhibited the following common characteristics:

- All cases involved groups of organizations with well-established positions in their ongoing businesses.
- All cases were intentionally time-limited endeavors.
- All cases were cross-industry collaborations where the participants had limited previous experiences of working together.
- All cases had explorative aims to simulate and test potential business models.
- All cases had visionary orientations based on future scenarios of profound industrial changes.

Individually, none of these are exclusive; most of them are shared with other kinds of interorganizational collaborations, such as strategic alliances and joint ventures. Taken together, however, the attributes appear to constitute a particular kind of network collaboration, where incumbent companies try to navigate emerging sustainability transitions by coming together across industrial boundaries to learn new ways of proposing, creating, and capturing value. Hence, in order to encapsulate this phenomenon, we introduce the concept of *experimental networks,* which, as is discussed in the following sections, adds nuance to our understanding of network collaborations in relation to business model innovation.

6. Discussion

This paper investigates a type of interorganizational collaboration aiming to enable business model innovation that, so far, has gained limited attention in research. To conceptualize the cross-industry character of the networks revealed in the cases, together with their time-limited durations and explorative, future oriented aims in relation to business model innovation we introduce the idea of experimental networks. In the following sections, we compare this concept to other interorganizational collaborations in relation to business model innovation and thereafter discuss some implications of experimental networks for research and practice.

6.1. The experimental network concept

Previous research has shown that many business models extend beyond limits of the firm and have an interorganizational nature. By introducing prefixes such as "open" (Chesbrough and Schwartz, 2007), "coopetition-based" (Ritala et al., 2014), "networked" (Palo and Tähtinen, 2013), and "network-embedded" (Bankvall et al., 2017), or suffixes such as "innovation alliances'' (Spieth et al., 2021), several studies have brought attention to how groups of organizations contribute to an overarching value proposition. The experimental networks identified from the cases here, however, differ from what is covered in extant literature in regard to interorganizational approaches for business model innovation. We propose the following definition: *an experimental network is a group of organizations collaborating in a time-limited, cross-industry network to explore potential business models for an anticipated, profound change in socio-technical systems.*

Most of the attributes in this definition are shared with other concepts of interorganizational collaborations for business model innovation. Indeed, an exploratory orientation of business model innovation efforts on nascent markets (McDonald and Eisenhardt, 2020), a multi-actor nature of business model innovation (Chesbrough and Schwartz, 2007; Ritala et al., 2014; Solaimani et al., 2018), and a time-limited duration of partner networks for business model innovation (Palo and Tähtinen, 2013; Solaimani et al., 2018), have all, at least implicitly, featured in extant literature. Taken together, however, the attributes in our definition appear to constitute a particular kind of network that has not received explicit attention in extant literature. In the following, the distinctiveness of the concept of experimental networks is discussed in comparison with other network concepts related to business model innovation. We focus especially on three concepts to illustrate these distinctions; "network-embedded business models" (Bankvall et al., 2017), "networked business models" (Palo and Tähtinen, 2013), and "business model innovation alliances" (Spieth et al., 2021).

As a first distinction, the duration of an experimental network is intentionally time limited. Thus, even if there might be implicit expectations that an experimental network constitutes a step towards new collaborations lasting beyond the end of the project, its closure constitutes a formal end of the participants' commitments, which creates an opportunity to make a decision to withdraw from, or continue, the collaboration after it has been tested. In this respect, the experimental networks resemble the networked business models (Palo and Tähtinen, 2013), while the business model innovation alliances and network-embedded business models constitute more long-term pursuits. In the first case, Spieth et al. (2020) address actors making ex ante decisions about strategic long-term collaborations (rather than an ex post decision on continuing after testing the collaboration in an experimental network), while in the second case Bankvall et al. (2017) primarily address the outcomes of new actor constellations as long term pursuits.

Second, an experimental network involves a group of organizations, which collaborate across established industrial boundaries and have a limited history of working together. By contrast, neither Bankvall et al. (2017) nor Spieth et al. (2020) emphasize the novelty of collaborations. Indeed, Spieth et al. (2020, p. 25) actually mention that the network partners "rely on their extant network to overcome their resource and knowledge constraints when striving for business model innovation", in other words the importance of using already existing relationships. The novelty, together with its cross-industry character, also makes the experimental network concept distinctly different from the network-embedded business models of Palo and Tähtinen (2013) with their empirical grounding in intra-industry collaborations.

Third, the technology focus is a distinction. While experimental networks explicitly revolve around the exploration of emerging technologies in their early phases, the networked business models are aimed at exploiting existing technologies in creative ways (Palo and Tähtinen, 2013). Furthermore, business model innovation alliances and network-embedded business models have mixed focuses, and as understood from their empirical cases can include both exploitation of existing technologies as well as exploration of emerging technologies (Bankvall et al., 2017; Spieth et al., 2021).

Fourth, the time horizon is a distinction. Even if the experimental networks are time-limited collaborations, they are based on a long-term vision of a potential, future commercial deployment. Previous studies vary in this regard. While the studies of Bankvall et al. (2017) and Spieth et al., 2021 reveal network collaborations with both short term and longterm commercial outcomes, Palo and Tähtinen (2013) primarily emphasize the deployment of business models within a short time frame and with quick gains.

Finally, experimental networks are formed around visions of potential changes in socio-technical systems and requiring profound redefinitions of current industrial structures. By contrast, the reported potential outcomes of other types of networks for business model innovation vary considerably (Bankvall et al., 2017; Spieth et al., 2021) and can be relatively local and incremental (Palo and Tähtinen, 2013). Thus, while the innovative changes addressed by these concepts are primarily on business models at the firm level or the network level, experimental networks are directed toward fundamental changes beyond existing businesses and industry structures and the envisioned business models beyond a potential transition.

To summarize, there are similarities between experimental networks and other network concepts in relation to business model innovation (see Table 6). However, when its features are considered together, the experimental network constitutes a category of its own. The combination of a time-limited duration, with a long term, visionary focus on systemic change requiring involvement of firms with varied backgrounds stands out as a specific type of collaborative setup for business model innovation.

6.2. Implications for research

Various scholars have proposed concepts to increase our understanding of how business model innovation unfolds through networks. In the previous subsection, we have described the concept of experimental networks and discussed its similarities and differences from other network concepts, i.e., theory elaboration by new construct specification (Fisher and Aguinis, 2017). In the following paragraphs we take this one step further and discuss the implications of the experimental networks concept in relation to two research strands: business model innovation in networks and sustainability transitions.

6.2.1. Literature on business model innovation in networks

Previous research has shown that many business models reflect a networked nature (Palo and Tähtinen, 2013; Bankvall et al., 2017) and has recognized the importance of interorganizational interactions in the development of new business models (Calia et al., 2007; Bouwman et al., 2008; Berglund and Sandström, 2013; Spieth et al., 2019). However, our paper suggests that established intra-industry relationships might be insufficient when incumbents attempt to innovate business models to navigate sustainability transitions. Instead, as we discuss through three empirical cases, incumbents are likely to allow parts of their organizations to engage in new actor constellations to experiment and collaborate in cross-industry settings, thus benefitting from access to complementary competences and pooling of resources from various industrial sectors. Accordingly, the findings extend the industrial network perspective by highlighting the need for cross-industry collaboration as an important source for business model innovation.

Table 6
Experimental networks compared to key network concepts for business model innovation.

	Network-embedded business model	Networked business model	Business model innovation alliance	Experimental network
Definition	"encompasses a set or network of firms involved in business exchanges that can only be understood and described at the network level" (Bankvall et al., 2017: p. 199)	"guides how a net of companies will create customer and network value by developing collective understanding of the business opportunities and shaping the actions to exploit them" (Palo and Tähtinen, 2013: p. 775)	"strategic partnerships that allow for coevally transforming and innovating the business models of the partner companies" (Spieth et al., 2021: p. 25)	"a group of organizations collaborating in a time-limited, cross-industry network, to explore potential business models for an anticipated, profound change in socio-technical systems"
Planned duration	Long-term pursuit	Time-limited project	Long-term pursuit	Time-limited project
Scope of interorganizational collaboration	Mixed	Intra-industry	Mixed	Cross-industry
Technology focus	Mixed	Exploitation of existing technologies	Mixed	Exploration of emerging technologies
Time horizon for commercial deployment	Mixed	Short-term	Mixed	Long-term
Scope of potential change	Mixed	Firm and network level	Firm and network level	Socio-technical system

Furthermore, previous research has highlighted how business models, framed as narratives, can function as boundary objects, directing and shaping future states (Doganova and Eyquem-Renault, 2009). Our findings extend this view by suggesting that an experimental network has a function beyond the narrative: it constitutes a time-limited embodiment of potential business models to be. Thus, it is not an implementation of a new business constellation; rather, it is a projection and test of a possible one. Consequently, the formation of experimental networks in relation to various sustainability challenges can be understood as market probes investigating emergent industry constellations years ahead of the commercialization of emerging technology. In this respect, business models are not just realizations of chosen strategies, they also function as tools for projecting and shaping the future.

6.2.2. Literature on business model innovation in sustainability transitions

In research on sustainability transitions, incumbent firms are usually described as defenders of the status quo, as late innovators, or as followers of innovative startups (Geels, 2014; Smink et al., 2015). There is, however, a growing research stream that recognizes how incumbents can enhance radical innovation by being active on the regime and niche levels simultaneously (Bergek et al., 2013; Berggren et al., 2015). Our findings align with this latter perspective and show how engagement in experimental networks can function as strategic attempts for incumbents to claim future positions in emerging transitions. As demonstrated, the conceptualization of such networks provides a theoretical grounding for analyzing agency in potential sustainability transitions. Hence, this conceptualization transcends the regime and niche dichotomy (Geels, 2014) and reveals one way for incumbents of a regime to claim agency with respect to emerging transitions. Thus, identifying the dynamics of experimental networks is one way for further enquiry into "hybrid forms of experimentation bridging the niche regime divide" (Sengers et al., 2019, p .162).

Moreover, in previous research, scholars have recognized the role of business models in the dynamics of sustainability transitions (e.g., Bohnsack et al., 2014), enhancing or blocking emerging triggers for potential systemic change (Bidmon and Knab, 2018). Our findings, however, suggest that in situations where there are strong pressures for systemic change and where several incumbents have to reconfigure their industry positions, business model innovation is a multiple-actor activity where experimental networks can be especially relevant. This means that in situations where an emerging transition demands mutual learning and adaptation, a focus on singular business models provides a limited, and sometimes maybe even false picture of what enables or hinders a transition. Thus, to acknowledge that many business models are often linked and interwoven with each other, there is a need to broaden the perspective on business models in studies of sustainability transitions. Experimental networks, as defined in this paper, is one concept to better capture how business model innovation for sustainability transition can be studied.

6.3. Implications for practice

6.3.1. Policy implications

The innovation policies to tackle global challenges, such as achieving sustainable development goals, are currently shifting towards formulating new public missions (Mazzucato, 2019; Hekkert et al., 2020). With such an ambition, the missions are expected to be "formulated in an open-ended way that encourages experimentation and diversity" and there is a need for "new forms of engagement and networks […] between public, private and third sector actors" (Schot and Steinmueller, 2018, p. 1564). This calls for the formation of new bridging networks and the experimentation of a range of anticipated future possibilities in parallel (Schot and Steinmueller, 2018). In this context, experimental networks, as described in this study, are a suitable instrument for fulfilling the formulated need. Consequently, supporting the formation of experimental networks is apposite at several policy levels: national, regional, local, etc. As sustainability transitions are systemic in that they cut across industries, organizations and administrative levels, policy instruments that can bridge and overcome administrative and industrial boundaries may trigger radical change. Furthermore, in contrast to the general policy practice of creating preconditions for development through regulations and funding, the creation of experimental networks offers a proactive instrument that can be used to drive a long-term vision. Therefore, experimental networks can be used in policy making to activate multiple sets of actors to explore scenarios of desired future states.

6.3.2. Management implications

From a managerial point of view, experimental networks could be seen as a means for exploring business model innovation to navigate sustainability transitions exhibiting emergent signs of potential futures. The advantage of using experimental networks is that they proactively create opportunities for learning and, consequently, avail the firm the possibility of claiming space in a socio-technical system to be. Accordingly, the managerial focus shifts from business model analysis to business model experimentation and from single firm focus to network focus. As our findings show, the experimental network can also be seen as a mediating instrument for testing business models ahead of deployment. By getting engaged in experimental networks, an organization can position itself for the future, as well as learn about the potential of the technology, gain negotiation power, legitimacy, funding, and support. As described, participation in an experimental network offers several benefits (e.g., pooling of resources, leveraging external support, gaining access to complementary competencies and a claimed space in a future business ecosystem), which are out of reach for a single organization or strategic alliance.

However, with participation in experimental networks also comes a responsibility. All participating actors have roles to play in the network. In addition, by engaging in this type of network, incumbents can complement their internal innovation processes. Since change in established organizations is typically an endeavor associated with many challenges, an experimental network can constitute a "sandbox" for variation and experimentation, buffered from daily operations. Nevertheless, engaging in experimental networks might also be associated with a number of risks, such as competence leakages, commitments leading to dead ends, drawing competitors' attention to a strategic opportunity, or simply wasting resources. Accordingly, a key managerial challenge is to both join the right experimental network and select the appropriate partner constellation.

6.4. Limitations and future research

This study has obvious methodological limitations as it is based on studies of three empirical cases from a similar cultural context, and where each study was limited to capturing the early, formative phase of an anticipated future transition. Consequently, we have only provided snapshots of the revealed network structures and have not covered the processual dynamics and structural adaptations of the projects unfolding over time. There is therefore a need for more studies of experimental networks in various types of industrial contexts and in various phases of systemic transition. All the three present cases were visionary and long-term explorations, but could experimental networks also be means for increased short-term exploitation, as well as for improvements of existing offerings, competences, or revenue models?

Furthermore, since the case studies were conducted *in situ* (and not in retrospect), they did not cover the outcomes of the experimental networks. At the time of the studies, it was impossible to assess whether the projects would be regarded as successes or failures in the future. Thus, whether initiating experimental networks is an effective or an ineffective strategy for business model innovation is an issue for future research. There is also a general need for more studies on various setups and configurations of experimental networks in different industries. Some examples of issues that need further enquiries are as follows: Are some organizations better than others in gaining advantages from participating in experimental networks? Are there specific ways of orchestrating these networks? Are different benefits associated with different contingencies and phases of a transition? What are the pathologies of experimental networks on the firm level and industry level?

7. Summary and conclusions

This paper introduces the concept of *experimental networks* to capture one way that incumbents organize for business model innovation when collaborating across industry boundaries in emerging sustainability transitions. Based on observations from three case studies, we suggest that an experimental network is a group of organizations collaborating in a time-limited, cross-industry network to explore potential business models for an anticipated profound change in socio-technical systems. To manage sustainability transitions the challenges of systemic innovation often need to be mitigated by novel collaborations beyond established industrial structures. Experimental networks constitute one type of means to address transition related challenges, such as the ambiguity of transition pathways, the contradiction between the established and potentially emerging business models, and the reconfiguration of networks across entrenched industrial sectors.

Appendix A. Topics covered in the interviews

The topics covered	Interview
● The past, present, and future of the eHighway E16 project; ● The motivation, roles and contribution of actors in the eHighway E16 project; ● The past, present, and future of sustainability transitions in long-haul, heavy duty road transportation; ● The electric road system technology and its potential for long haul, heavy-duty road transportation.	IN1, IN2, IN3, IN4, IN5, IN6
● The structure and characteristics of the iron and steelmaking industry; ● The past, current status and future of sustainability transitions in the iron and steelmaking industry; ● Emerging innovations and their potential in the iron and steelmaking industry; ● Motives, drivers and barriers for the Hybrit project.	IN7, IN8
● The current status and future of sustainability transitions in the industry; ● The roles of actors and policy support in the Hybrit project; ● The dynamics between actors and the vision of the Hybrit project.	IN9, IN10, IN11
● The current status and the timeline of the Hybrit project; ● The motivation, roles and contribution of actors in the Hybrit project; ● Organizational, technological and financial aspects of the Hybrit project; ● Potential business effects of the Hybrit project.	IN12, IN13
● The current status and future of sustainability transitions in the public transportation industry; ● The motivation, roles and contribution of actors in the Autopilot project and its follow-up project in Barkarby; ● Organizational, technological and financial aspects of the autonomous mobility projects; ● Potential business effects of self-driving bus technology.	IN14, IN15, IN16
● The motivation, roles and contribution of actors in the Autopilot project; ● Challenges and learnings of the Autopilot project; ● Potential business effects of self-driving bus technology.	IN17, IN18
● The current status and future of sustainability transitions in the public transportation industry; ● Emerging technological and service innovations in the public transportation industry; ● The motivation and roles of actors in the autonomous mobility projects; ● Potential business effects of self-driving bus technology.	IN19, IN20

References

Al-Debei, M.M., Avison, D., 2010. Developing a unified framework of the business model concept. Eur. J. Inf. Syst. 19 (3), 359–376.

Alvesson, M., Skoldberg, K., 2000. Reflexive Methodology: New Vistas for Qualitative Research. SAGE.

Bankvall, L., Dubois, A., Lind, F., 2017. Conceptualizing business models in industrial networks. Ind. Market. Manag. 60, 196–203.

Barratt, M., Choi, T.Y., Li, M., 2011. Qualitative case studies in operations management: trends, research outcomes, and future research implications. J. Oper. Manag. 29, 329–342.

Bergek, A., Berggren, C., Magnusson, T., Hobday, M., 2013. Technological discontinuities and the challenge for incumbent firms: destruction, disruption or creative accumulation? Res. Pol. 42 (6–7), 1210–1224.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. Res. Pol. 37 (3), 407–429.

Berggren, C., Karabag, S.F., 2019. Scientific misconduct at an elite medical institute: the role of competing institutional logics and fragmented control. Res. Pol. 48 (2), 428–443.

Berggren, C., Magnusson, T., Sushandoyo, D., 2015. Transition pathways revisited: established firms as multi-level actors in the heavy vehicle industry. Res. Pol. 44 (5), 1017–1028.

Berglund, H., Sandström, C., 2013. Business model innovation from an open systems perspective: structural challenges and managerial solutions. Int. J. Prod. Dev. 18 (3/4), 274–285.

Berkhout, F., Verbong, G., Wieczorek, A., Raven, R., Lebel, L., Bai, X., 2010. Sustainability experiments in Asia: innovations shaping alternative development pathways? Environ. Sci. Pol. 13 (4), 261–271.

Bidmon, C.M., Knab, S.F., 2018. The three roles of business models in societal transitions: new linkages between business model and transition research. J. Clean. Prod. 178, 903–916.

Bohnsack, R., Pinkse, J., Kolk, A., 2014. Business models for sustainable technologies: exploring business model evolution in the case of electric vehicles. Res. Pol. 43 (2), 284–300.

Bolton, R., Hannon, M., 2016. Governing sustainability transitions through business model innovation: towards a systems understanding. Res. Pol. 45 (9), 1731–1742.

Bouwman, H., De Vos, H., Haaker, T., 2008. Mobile Service Innovation and Business Models. Springer.

Bouwman, H., De Reuver, M., Hampe, F., Carlsson, C., Walden, P., 2014. Mobile RD prototypes — what is hampering market implementation? Int. J. Innovat. Technol. Manag. 11, 1–18, 01.

Bucherer, E., Eisert, U., Gassmann, O., 2012. Towards systematic business model innovation: lessons from product innovation management. Creativ. Innovat. Manag. 21 (2), 183–198.

Calia, R.C., Guerrini, F.M., Moura, G.L., 2007. Innovation networks: from technological development to business model reconfiguration. Technovation 27 (8), 426–432.

Chesbrough, H., 2006. Open Business Models: How to Thrive in the New Innovation Landscape. Harvard Business Press.

Chesbrough, H., 2007. Why companies should have open business models. MIT Sloan Manag. Rev. 48 (2).

Chesbrough, H., 2010. Business model innovation: opportunities and barriers. Long. Range Plan. 43 (2–3), 354–363.

Chesbrough, H., Rosenbloom, R.S., 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. Ind. Corp. Change 11 (3), 529–555.

Chesbrough, H., Schwartz, K., 2007. Innovating business models with co-development partnerships. Res. Technol. Manag. 50 (1), 55–59.

Christensen, C.M., 2006. The ongoing process of building a theory of disruption. J. Prod. Innovat. Manag. 23 (1), 39–55.
Demil, B., Lecocq, X., 2010. Business model evolution: in search of dynamic consistency. Long. Range Plan. 43, 227–246.
Desyllas, P., Sako, M., 2013. Profiting from business model innovation: evidence from Pay-As-You-Drive auto insurance. Res. Pol. 42, 101–116.
Dijk, M., Orsato, R.J., Kemp, R., 2013. The emergence of an electric mobility trajectory. Energy Pol. 52, 135–145.
Doganova, L., Eyquem-Renault, M., 2009. What do business models do?. Innovation devices in technology entrepreneurship. Res. Pol. 38 (10), 1559–1570.
Doz, Y.L., Kosonen, M., 2010. Embedding strategic agility: a leadership agenda for accelerating business model renewal. Long. Range Plan. 43 (2–3), 370–382.
Dubois, A., Gadde, L.E., 2002. Systematic combining: an abductive approach to case research. J. Bus. Res. 55, 553–560.
Dubois, A., Gadde, L.E., 2014. 'Systematic combining'-A decade later. J. Bus. Res. 67 (6), 1277–1284.
Edmondson, A.C., McManus, S.E., 2007. Methodological fit in management field research. Acad. Manag. Rev. 32 (4), 1155–1179.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550.
Eisenhardt, K.M., 2021. What is the Eisenhardt Method, really? Strat. Organ. 19 (1), 147–160.
El Sawy, O.A., Pereira, F., 2013. Business Modelling in the Dynamic Digital Space: an Ecosystem Approach, SpringerBriefs in Digital Spaces. Springer, Berlin, Heidelberg.
Fisher, G., Aguinis, H., 2017. Using theory elaboration to make theoretical advancements. Organ. Res. Methods 20 (3), 438–464.
Foss, N.J., Saebi, T., 2017. Fifteen years of research on business model innovation: how far have we come, and where should we go? J. Manag. 43 (1), 200–227.
Foss, N.J., Saebi, T., 2018. Business models and business model innovation: between wicked and paradigmatic problems. Long. Range Plan. 51 (1), 9–21.
Garud, R., Gehman, J., Tharchen, T., 2018. Performativity as ongoing Journeys : implications for strategy, entrepreneurship, and innovation. Long. Range Plan. 51 (3), 500–509.
Geels, F.W., 2005. The dynamics of transitions in socio-technical systems: a multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technol. Anal. Strat. Manag. 17 (4), 445–476.
Geels, F.W., 2012. A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. J. Transport Geogr. 24 (C), 471–482.
Geels, F.W., 2014. Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective. Theor. Cult. Soc. 31, 21–40, 5.
Geels, F.W., 2018. Disruption and low-carbon system transformation: progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. Energy Res. Soc. Sci. 37, 224–231.
Geels, F.W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., Wassermann, S., 2016. The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990-2014). Res. Pol. 45 (4), 896–913.
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Pol. 36 (3), 399–417.
Haaker, T., Bouwman, H., Janssen, W., de Reuver, M., 2017. Business model stress testing: a practical approach to test the robustness of a business model. Futures 89, 14–25.
Hacklin, F., Björkdahl, J., Wallin, M.W., 2018. Strategies for business model innovation: how firms reel in migrating value. Long. Range Plan. 51 (1), 82–110.
Håkansson, H., Snehota, I., 1989. No business is an island: the network concept of business strategy. Scand. J. Manag. 5, 187–200.
Håkansson, H., Ford, D., 2002. How should companies interact in business networks? J. Bus. Res. 55, 133–139.
Håkansson, H., Ford, D., Gadde, L.E., Snehota, I., Waluszewski, A., 2009. Business in Networks. John Wiley, Chichester.
Hekkert, M.P., Janssen, M.J., Wesseling, J.H., Negro, S.O., 2020. Mission-oriented innovation systems. Environ. Innov. Soc. Transit. 34, 76–79.
Hoogma, R., Kemp, R., Schot, J.W., Truffer, B., 2002. Experimenting for Sustainable Transport: the Approach of Strategic Niche Management. Spon Press.
IEA, 2019. Tracking industry. https://www.iea.org/reports/tracking-industry-2019.
Johanson, J., Mattsson, L.G., 1987. Interorganizational relations in industrial systems: a network approach compared with the transaction-cost approach. Int. Stud. Manag. Organ. 17 (1), 34–48.
Johnson, M.W., Christensen, C.M., Kagermann, H., 2008. Reinventing your business model. Harv. Bus. Rev. 59–67.
Karakaya, E., Nuur, C., Assbring, L., 2018. Potential transitions in the iron and steel industry in Sweden: towards a hydrogen-based future? J. Clean. Prod. 195, 651–663.
Kaulio, M., Thorén, K., Rohrbeck, R., 2017. Double ambidexterity: how a Telco incumbent used business-model and technology innovations to successfully respond to three major disruptions. Creativ. Innovat. Manag. 26, 339–352.
Khanagha, S., Volberda, H., Oshri, I., 2014. Business model renewal and ambidexterity: structural alteration and strategy formation process during transition to a Cloud business model. RD Manag. 44 (3), 322–340.
Kumaraswamy, A., Garud, R., Ansari, S.S., 2018. Perspectives on disruptive innovations. J. Manag. Stud. 55 (7), 1025–1042.
Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Wells, P., 2019. An agenda for sustainability transitions research: state of the art and future directions. Environ. Innov. Soc. Transit. 31, 1–32.
Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Res. Pol. 41 (6), 955–967.
Markides, C.C., 2006. Disruptive innovation: in need of better theory. J. Prod. Innovat. Manag. 23 (1), 19–25.
Massa, L., Tucci, C., Afuah, A., 2017. A critical assessment of business model research. Acad. Manag. Ann. 11 (1), 73–104.
Mauborgne, R., Kim, W.C., 2005. Blue Ocean Strategy. Harvard Business School Publishing Corporation, Boston, Massachusetts.
Mazzucato, M., 2019. Catch-up and mission-oriented innovation. In: Oqubay, A., Ohno, K. (Eds.), How Nations Learn: Technological Learning, Industrial Policy, and Catch-Up, pp. 63–81 (Oxford University Press.).
McDonald, R.M., Eisenhardt, K.M., 2020. Parallel play: startups, nascent markets, and effective business-model design. Adm. Sci. Q. 65 (2), 483–523.
McGrath, R.G., 2010. Business models: a discovery driven approach. Long. Range Plan. 43 (2–3), 247–261.
Morris, M., Schindehutte, M., Allen, J., 2005. The entrepreneur's business model: toward a unified perspective. J. Bus. Res. 58, 726–735.
Nill, J., Kemp, R., 2009. Evolutionary approaches for sustainable innovation policies: from niche to paradigm? Res. Pol. 38 (4), 668–680.
Osterwalder, A., Pigneur, Y., 2010. Business Model Generation: a Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons.
Palo, T., Tähtinen, J., 2013. Networked business model development for emerging technology-based services. Ind. Market. Manag. 42 (5), 773–782.
Ridder, H.G., 2017. The theory contribution of case study research designs. Bus. Res. 10 (2), 281–305.
Rip, A., Kemp, R., 1998. Technological change. In: Malone, S. Rayner E.L. (Ed.), Human Choice and Climate Change. Vol. II, Resources and Technology, pp. 327–399 (Battelle Press).
Ritala, P., Golnam, A., Wegmann, A., 2014. Coopetition-based business models: the case of Amazon.com. Ind. Market. Manag. 43 (2), 236–249.
Rotmans, J., Loorbach, D., 2009. Complexity and transition management. J. Ind. Ecol. 13 (2), 184–196.
Sabatier, V., Craig-Kennard, A., Mangematin, V., 2012. When technological discontinuities and disruptive business models challenge dominant industry logics: insights from the drugs industry. Technol. Forecast. Soc. Change 79 (5), 949–962.
Sabatier, V., Mangematin, V., Rousselle, T., 2010. From recipe to dinner: business model portfolios in the European biopharmaceutical industry. Long. Range Plan. 43 (2–3), 431–447.
Sandström, C.G., 2010. A Revised Perspective on Disruptive Innovation: Exploring Value, Networks and Business Models.
Santos, J., Spector, B., Van der Heyden, L., 2009. Toward a theory of business model innovation within incumbent firms. INSEAD.
Schaltegger, S., Lüdeke-Freund, F., Hansen, E.G., 2016. Business models for sustainability: a Co-evolutionary analysis of sustainable entrepreneurship, innovation, and transformation. Organ. Environ. 29 (3), 264–289.
Schot, J., Steinmueller, W.E., 2018. Three frames for innovation policy: RD, systems of innovation and transformative change. Res. Pol. 47 (9), 1554–1567.
Sengers, F., Wieczorek, A.J., Raven, R., 2019. Experimenting for sustainability transitions: a systematic literature review. Technol. Forecast. Soc. Change 145, 153–164.
Siggelkow, N., 2001. Change in the presence of Fit : the rise, the fall, and the renaissance of liz claiborne. Acad. Manag. J. 44 (4), 838–857.
Siggelkow, N., 2007. Persuasion with case studies. Acad. Manag. J. 50 (1), 20–24.
Smink, M.M., Hekkert, M.P., Negro, S.O., 2015. Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies. Bus. Strat. Environ. 24 (2), 86–101.
Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Res. Pol. 34, 1491–1510.
Solaimani, S., Bouwman, H., Itälä, T., 2015. Networked enterprise business model alignment: a case study on smart living. Inf. Syst. Front 17, 871–887.
Solaimani, S., Heikkilä, M., Bouwman, H., 2018. Business model implementation within networked enterprises: a case study on a Finnish pharmaceutical project. Eur. Manag. Rev. 15 (1), 79–96.
Sosna, M., Trevinyo-Rodríguez, R.N., Velamuri, S.R., 2010. Business model innovation through trial-and-error learning: the Naturhouse case. Long. Range Plan. 43 (2–3), 383–407.
Spieth, P., Laudien, S.M., Meissner, S., 2021. Business model innovation in strategic alliances: a multi-layer perspective. R&D Management 51 (1), 24–39.
Spieth, P., Meissner, S., 2018. Business model innovation alliances: how to open business models for cooperation. Int. J. Innovat. Manag. 22 (4).
Spieth, P., Roeth, T., Meissner, S., 2019. Reinventing a business model in industrial networks: implications for customers' brand perceptions. Ind. Market. Manag. 83, 275–287.
Spieth, P., Schneckenberg, D., Ricart, J.E., 2014. Business model innovation–state of the art and future challenges for the field. RD Manag. 44 (3), 237–247.
St Pierre, E.A., Jackson, A.Y., 2014. Qualitative data analysis after coding. Qual. Inq. 20 (6), 715–719.
Susur, E., Karakaya, E., 2021. A reflexive perspective for sustainability assumptions in transition studies. Environ. Innov. Soc. Transit. 39, 34–54.
Teece, D.J., 2010. Business models, business strategy and innovation. Long. Range Plan. 43, 172–194.
Tongur, S., 2018. Preparing for Takeoff: Analyzing the Development of Electric Road Systems from a Business Model Perspective. KTH Royal Institute of Technology, Stockholm, Sweden. PhD Dissertation.
Tongur, S., Engwall, M., 2014. The business model dilemma of technology shifts. Technovation 34 (9), 525–535.

Tongur, S., Engwall, M., 2017. Exploring window of opportunity dynamics in infrastructure transformation. Environ. Innov. Soc. Transit. 25, 82–93.
Tripsas, M., Gavetti, G., 2000. Capabilities, cognition, and inertia: evidence from digital imaging. Strat. Manag. J. 21 (10–11), 1147–1161.
Turnheim, B., Geels, F.W., 2013. The destabilisation of existing regimes: confronting a multi-dimensional framework with a case study of the British coal industry (1913-1967). Res. Pol. 42, 1749–1767.
Van der Laak, W.W.M., Raven, R.P.J.M., Verbong, G.P.J., 2007. Strategic niche management for biofuels: analysing past experiments for developing new biofuel policies. Energy Pol. 35 (6), 3213–3225.
van Waes, A., Farla, J., Frenken, K., de Jong, J.P.J., Raven, R., 2018. Business model innovation and socio-technical transitions. A new prospective framework with an application to bike sharing. J. Clean. Prod. 195, 1300–1312.
Wang, Q., Berlin, D., Meijer, S., 2019. Uncovering stakeholder influences in electric road systems using two assessment methods: the case of eRoadArlanda. Res. Transport. Bus. Manag. 33, 1–20.
Wells, P., Nieuwenhuis, P., 2012. Transition failure: understanding continuity in the automotive industry. Technol. Forecast. Soc. Change 79, 1681–1692.
Yin, R.K., 2014. Case Study Research: Design and Methods, fifth ed. SAGE, California.
Zolfagharian, M., Walrave, B., Raven, R., Romme, A.G.L., 2019. Studying transitions: past, present, and future. Res. Pol. 48 (9).
Zott, C., Amit, R., 2013. The business model: a theoretically anchored robust construct for strategic analysis. Strat. Organ. 11 (4), 403–411.
Zott, C., Amit, R., 2010. Business model design: an activity system perspective. Long. Range Plan. 43, 216–226.
Zott, C., Amit, R., Massa, L., 2011. The business model: recent developments and future research. J. Manag. 37 (4), 1019–1042.