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A heroic vision for sustainability transitions: electrification through collaborative supply chain networks

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Abstract

Purpose – This study aims to investigate how actor collaboration facilitates a sustainability transition by exploring the challenges and facilitators in electrifying construction transport.

Design/methodology/approach – A qualitative interview study was conducted with both private and public sector participants. The data are based on 18 interviews with experts from municipalities, innovation hubs, networking agencies, energy companies and construction firms. The interview data, along with webpages and reports, were coded using the Gioia Methodology.

Findings – The study provides an integrated vision of sustainability transition, highlighting the interplay between persistent "chicken-and-egg" dilemmas and the emergence of actors identified as "heroes." The dilemmas involve highly interconnected resource issues, including limited physical resources, low motivation and insufficient knowledge. In the face of these challenges, individuals who work to establish collaborative networks, promote fair transitions and advocate for common practices are recognized as "heroes" in this transition.

Research limitations/implications – The focus of this study is limited to the electrification of the construction transport in Sweden.

Practical implications – The findings inform managers and policymakers pursuing sustainability objectives, providing actionable insights and a shared vision throughout supply chain networks.

Originality/value – The findings highlight how supply chain networks, comprising private and public organizations, promote a sustainability transition in an industry known for its conservative nature and short-term business relationships.

Keywords Supply chain collaboration, Network, Sustainability transition, Electrifying construction transport

Paper type Research paper

1. Introduction

To enable sustainability transition within and across industries, actors need to interact to diffuse sustainability in their supply chain networks (Johnsen *et al.*, 2022; Meqdadi *et al.*, 2020; Ratsimandresy and Miemczyk, 2024). These interactions involve a wide range of actors, including customers, suppliers, governmental actors, regulators, intermediaries, NGOs and other external stakeholders (Alinaghian *et al.*, 2021; Melander and Pazirandeh, 2019). Interacting horizontally and vertically in supply chain networks is complex and involves a wide range of business relationships (Miemczyk *et al.*, 2016; Huang *et al.*, 2020). Such collaborations aimed to improve sustainability in the supply chain requires actors to focus on goal congruence and knowledge sharing (Colombo *et al.*, 2025; Kitsis and Chen, 2023). Combining vertical and horizontal interaction enables a diverse set of actors to collaborate to provide innovative solutions (Solaimani and van der Veen, 2021) contributing to a sustainable transition.

Significant efforts are being made to transition the traditional transport sector with a strong focus on sustainability. In road transportation, electrification has emerged as a leading solution, supported by government confidence and extensive research into private electric vehicles (EVs) (Patil *et al.*, 2023). Promoting electrification involves multiple strategies that vary across different countries and contexts (Jain *et al.*, 2024). While private EVs have received considerable attention, there is a noticeable gap in focus regarding the electrification of commercial and heavy vehicles. This sector has lagged in adoption but holds promising potential (Al-Hanahi *et al.*, 2021). To achieve the goal of fossil-free construction sites and transports, initiatives are being developed to electrify heavy construction machinery and vehicles (C40 Cities Climate Leadership Group, 2020; Federation, 2018). Although several pilot projects have been implemented, few have been scaled up and integrated as standard solutions. The slow adoption of new technology in the construction industry is often attributed to

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cost concerns, resistance to change and its fragmented structure (Alsofiani, 2024).

Against this backdrop, Sweden provides a particularly interesting case, as it has set ambitious environmental targets for both transport and the construction industry. Notably, transport and excavation activities within the construction sector alone account for approximately 4%–5% of the country's total CO_2 emissions (Electricity, 2023a, 2023b). The challenges to large-scale electrification are primarily rooted in existing business models and organizational structures rather than technological limitations (Fossilfritt Sverige, 2024). The construction industry features a complex, project-based supply chain that involves various stakeholders, including developers, contractors, subcontractors, suppliers and logistics providers. Efforts to enhance supply chain integration have been explored (Hallberg and Mogéus, 2016), including the introduction of construction logistics setups to improve the previously *ad hoc* approach (Fredriksson *et al.*, 2024). To encourage flexibility and innovation among Swedish small and medium-sized enterprises, horizontal supply chain collaboration has proven effective in promoting resource and knowledge sharing (Björnfot and Torjussen, 2012).

Using the lens of sustainability transition, the deeper barrier hindering the transition of the construction industry can be identified as dysfunctional social interaction (Martek *et al.*, 2019), including complacency, passive government, vested interest and lack of leadership. A "collective good" transition such as electrifying transport does not provide obvious benefits for business customers, and the existing systems need to be reoriented for introducing complementary assets (Geels, 2011). These imply a long-term change that involves multiple actors and entails coevolution and multidimensional interactions between technologies, industry structures, markets, policies and culture (Fredriksson and Huge-Brodin, 2022; Köhler *et al.*, 2019; Melander and Lind, 2022). Open-endedness, uncertainty and disagreement are also unavoidable in the sustainability transition, encapsulated by Hallin *et al.* (2021, p. 1948) as "transition toward sustainability always involves the transition of sustainability." These systemic uncertainties are further compounded by technological choices in sustainable transport. Both battery-driven EVs and hydrogen-fueled freight vehicles face common challenges such as insecure sources of alternative energy, limited infrastructure and high initial costs (Shardeo and Sarkar, 2024).

Supply chain management (SCM) research is helpful for understanding a supply chain network's transition to sustainability (Alinaghian *et al.*, 2021; Johnsen *et al.*, 2022). Collaborative supply chain networks can serve as enablers for sustainability initiatives, where the nature of the relationships between the actors is a predictor of the outcomes of such initiatives (Saunders *et al.*, 2019). The construction sector shows similar results, where close and open collaboration between involved actors is key to lowering emissions from transport (Stokke *et al.*, 2023; Venås *et al.*, 2020). Such collaborations need to include a wide range of actors, such as public buyers, construction companies, subcontractors and equipment suppliers, making the supply chain network complex. While several studies and reports highlight the importance of electrifying the construction sector and the necessity of supply chain network collaborations (Fredriksson and Huge-Brodin, 2022; Fredriksson *et al.*, 2021; Sezer and Fredriksson, 2021), there are still uncertainties regarding how such a sustainability transition can be achieved.

This study examines the practical aspects of electrifying both onsite and offsite transport within Sweden's construction industry. Its objective is to investigate the transition toward large-scale adoption of electric machinery and vehicles, highlighting the role of collaborative supply chain networks in facilitating this change. The study is guided by two research questions (RQs):

RQ1. What are the key challenges associated with electrifying transport in Sweden's construction industry?

RQ2. How can collaboration across supply chain networks promote a sustainability transition in Sweden's construction sector?

2. Theoretical background

2.1 Sustainability transition

Sustainability transition is a grand socio-technical imagination of our time projecting an infinite future of humans and Earth (Beck *et al.*, 2021). The imaginaries of sustainability transition are not merely "strategic and action-forcing representations of the world as it is, but also concurrent representations of how collectives want that world to be" (Beck *et al.*, 2021). Such a vision necessitates long-term transformation across economic, environmental and social dimensions. This transformation must involve multiple stakeholders and require the coevolution and interaction of technologies, industry structures, markets, policies and culture (Köhler *et al.*, 2019). One dominant way of approaching sustainability transition is the multilevel perspective (MLP), which depicts the overall dynamics between the niches, regimes and landscapes in the transition (Markard *et al.*, 2012). As responses to the critics toward MLP (lack of agency, unclear operationalization and ambiguity in the concept regime and bias toward bottom-up change models), Geels (2011) suggests dropping the notion of hierarchy in favor of flat ontologies, where outcomes are shaped by actors who combine and reproduce different elements such as technology, meaning and skills.

Aligned with this proposal, efforts have aimed to enrich the MLP framework. Markard and Truffer (2008) developed an integrated framework combining technological innovation systems and MLP, bridging the conceptual gap between the niche and regime levels via system dynamics. From a political ecology perspective, Lawhon and Murphy (2012) proposed an enhancement to the MLP framework by emphasizing the importance of questioning how problems are defined. They advocated for the inclusion of a more diverse range of actors, knowledge systems and worldviews in sustainability transitions. In response to long-standing critiques regarding the MLP's limited treatment of agency, Geels (2020) introduced a multidimensional model that draws on social constructivism, evolutionary economics and neo-institutional theory. This enriched framework highlights the roles of actors in shaping transitions through strategic actions, learning processes and institutional work. Consequently, it reframes transitions as evolutionary, interpretive and conflictual processes.

The emphasis on actors and more microdynamics aligns with the performative perspective of sustainability transition, seeking to develop a deeper and more inclusive understanding of "the actual dynamics of sustainability transition, not as defined theoretically or envisioned politically, but as they are shaped by the everyday practices of individuals and organizations" (Hallin *et al.*, 2021, p. 1950). This approach embraces the open-endedness, uncertainty and disagreements inherent in the sustainability transition. It requires the actors to respond and adapt to a wide range of potential risks and uncertainties, which is central to resilience thinking that has rarely been integrated into discussions on sustainability (Scordato and Gulbrandsen, 2024). Furthermore, resilience thinking brings attention to issues of fairness in the transition, shifting from technology to a more holistic perspective encompassing broader social and environmental considerations (Scordato and Gulbrandsen, 2024).

In practice, actors can align their visions as a collective network when innovating and commercializing new technological solutions during the transition. Farla *et al.* (2012) examined sustainability transitions from the perspectives of actors, strategies and resources, demonstrating that these processes do not arise from unintentional interactions among players pursuing their own agendas. Instead, they tend to be strategically shaped by actors with a broader vision. Corazza *et al.* (2022) illustrate how a network of smaller actors can exert influence by developing policies that support these smaller entities in engaging in sustainable innovations. Furthermore, pro-renewable actors, such as NGOs and local governments, are not entirely passive during periods of political instability caused by the central government's actions; they actively seek opportunities to move forward together, albeit on a smaller scale (Aguiar-Hernandez and Breetz, 2024).

The transition to sustainable supply chain networks is a dynamic process, which engages actors on multiple levels, ranging from the individual and their organization to complete supply chain networks (Touboulic *et al.*, 2018). As SCM research on sustainability in supply chains grows, the focus has shifted from first-tier suppliers toward investigating sustainability in supply chain networks (Alinaghian *et al.*, 2021; Melander and Arvidsson, 2022; Miemczyk *et al.*, 2012). A study on extending sustainability across a transport supply chain network showed that sustainability requirements need to be adapted to the different contexts to enable fruitful implementation (Forslund *et al.*, 2022). In this aspect, collaboration among supply chain network actors is a prerequisite for understanding both environmental and social sustainability requirements. Diffusion of sustainability along the supply chain network is challenging, where organizations need to address the cost of sustainability, knowledge gap, lack of infrastructure and supply chain complexity (Oyedijo *et al.*, 2024). In this challenging environment, business relationships with multiple actors in the supply chain network are vital.

2.2 Business relationships in construction supply chain networks

The industrial marketing and purchasing (IMP) literature assumes that actors collaborate with one another within the business landscape, forming networks (Snehota, 2011; Snehota and Hakansson, 1995). These networks and relationships evolve as actors enter or exit the network and as the motivations and willingness of the involved actors change (Guercini and Runfola, 2012). As the network evolves, the roles of actors also change; for example, an actor may assume one role during an innovation phase, which then transforms into another role during the implementation phase. In networks, relationships are built through interaction, often through long-term collaborations. Actors engage in networks because no single actor controls all the resources necessary to perform the activities required to operate a business (Gadde *et al.*, 2010; Snehota, 2011). The resources involved can vary widely, including tangible assets like factories or production equipment, as well as intangible resources such as knowledge (Sundquist and Melander, 2021). The activities that actors undertake include production, logistics, administration, deliveries, information handling, services, innovation and so on. Interaction and resource combining are often considered important enablers of innovation in networks (Landqvist and Lind, 2019), as actors need to combine knowledge to develop new sustainable products, services or processes (Melander and Arvidsson, 2022).

While the construction industry is generally viewed as traditional and lacking in innovativeness, there is a growing emphasis on environmental concerns, particularly the need to reduce CO_2 emissions throughout the supply chain network (Eriksson *et al.*, 2021). This shift toward sustainability necessitates the creation of new relationships between firms within the sector, especially to foster a more sustainable construction industry. To enhance sustainability in construction logistics, actors must collaborate with those who are typically outside their existing business networks (Fredriksson and Huge-Brodin, 2022). However, building long-term relationships in this industry is challenging owing to its project-based nature, which often results in temporary network relationships. Additionally, competitive tendering and time-limited projects lead to few long-term strategic relationships within the industry (Gadde and Dubois, 2010). These features limit the possibility of exploiting interfaces as investments (Eriksson *et al.*, 2021). Markets operating under public procurement rules, such as large parts of the construction industry, cannot interact owing to regulations. It is suggested that the construction industry could transform toward strategic partnering by extending their collaboration through both time and space (Sundquist *et al.*, 2018). Actors can enhance their relationships with suppliers over time and broaden their networks through increased collaboration on various projects. However, construction projects can be quite complex. For instance, studying the construction of a hospital reveals the intricate interdependencies that exist between networks of interconnected facilities and organizational units (Wagrell *et al.*, 2022). As pointed out by Fredriksson and Huge-Brodin (2022), the interconnected nature of actors' influence in the construction logistics system complicates the implementation of sustainability transition.

2.3 Framework for actor collaboration in sustainability transition

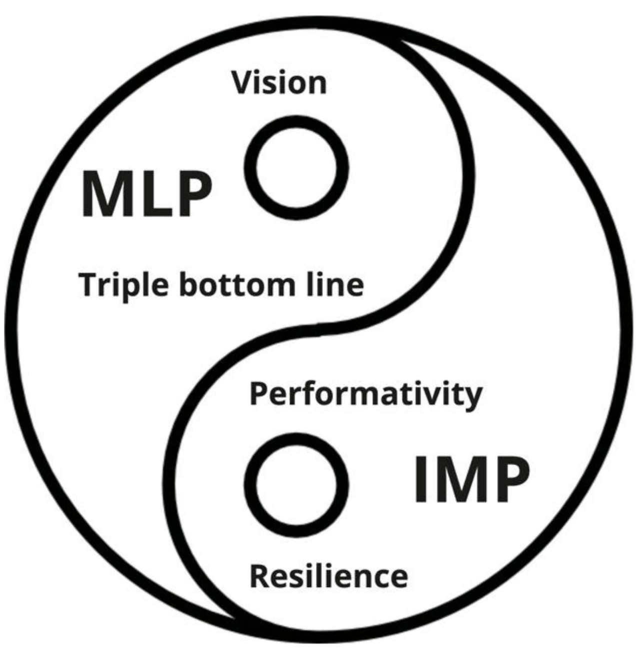
Although previous attempts to enrich sustainability transition analysis beyond the MLP have yielded valuable insights, they remain largely abstract and descriptive. They offer little guidance for examining how networks form, evolve, mobilize resources and coordinate activities – particularly within traditional construction supply chain contexts. The IMP perspective addresses this gap by providing a relational and horizontal lens for understanding actor constellations and resource mobilization in sustainability transitions. This synthesis helps bridge the gap between high-level MLP patterns and the day-to-day practices of actors embedded in a specific transition context.

To visualize the dynamics of actor collaboration in sustainability transitions, we have developed a framework that illustrates the relationships between key theoretical concepts used in our analysis. As shown in Figure 1, the yin-yang symbol represents the interplay among various aspects of sustainability transitions discussed above. The MLP offers an overview of these dynamics, providing a high-level understanding similar to the concepts of "vision" and the "triple bottom line." In contrast, the IMP perspective, which focuses on business networks, provides a practical lens for understanding actor collaboration, aligning with the principles of "performativity" and "resilience." Yin-yang is a suitable illustration, as it is a philosophical concept embracing paradox, dynamics and change (Liu and An, 2021), which resonates with the challenge of balancing our strategy/ambition and action/adaptability in promoting sustainability transitions. Especially in the predevelopment and exploration phase, a dynamic equilibrium often emerges, characterized by invisible changes driven by the tension between the desire for new possibilities and the resistance to changing existing configurations (Kivimaa *et al.*, 2019). Overall, the IMP perspective can complement the MLP perspective by offering practical strategies (focused on actors, resources and activities), leading to a more integrated vision for facilitating sustainability transition.

3. Methodology

This research is based on an interview study in Sweden and was conducted in an exploratory way to understand the phenomenon (Eisenhardt and Graebner, 2007) of electrifying construction

Figure 1 Theoretical framework of sustainability transition



Source: Authors own work

transport. An exploratory study is appropriate because the electrification of construction transports is in the early predevelopment and exploration stage (Kivimaa *et al.*, 2019). As shown in the sustainability reports of leading construction companies, electric construction machinery and vehicles are still in the trial phase, where no commercial electrified sites exist yet, only some small-scale pilot projects (Electricity, 2023a, 2023b). For example, the electra project focuses on electrifying building logistics and studying the impact on trucks and charging infrastructure (Electricity, 2023a). The Electric Worksites project tests different battery electric construction equipment, including compact and 30-ton machines (Electricity, 2023b). Promising test beds for larger constructions, such as Älvstaden in Gothenburg (Göteborgs Stad, 2023), might provide fruitful avenues for further testing.

Relevant organizations were initially identified through homepages and project descriptions; experts were connected with the help of these organizations and networking events. Subsequently, we used a snowballing approach, recognizing that knowledge at this early stage of electrification is spread across various stakeholders. Eighteen industrial experts were interviewed from March 2023 to October 2023, with their profiles shown in Table 1. Each interview lasted approximately 1 h on average (the interview guide is included in the Appendix). Regardless of their roles or experience, the most advanced stage of electrification that respondents have participated in so far is pilot projects, validating that the transition is still in its early phase.

In terms of the sample size, Guest *et al.* (2006) suggested that saturation often occurs within the first 12 interviews, with basic themes emerging as early as six interviews. Similarly, Hennink and Kaiser (2022) found that code saturation can be achieved with 9–17 interviews. However, recent methodological discussions have questioned the traditional idea of data saturation (Braun and Clarke, 2019). By abandoning the idea of data saturation, we recognize that data collection in this study could theoretically continue indefinitely to uncover new insights. This openness does not weaken the rigor of our qualitative analysis, which adheres to the transparent and structured approach recommended by the Gioia methodology (Gioia *et al.*, 2013). Considering the interviewees' background in Table 1 and the representative quotations in Tables 2 and 3, we believe that readers are well-prepared to evaluate the quality of the data and the robustness of the proposed theoretical model shown in Figure 2. This approach resonates with the principles of information power (Malterud *et al.*, 2016) and theoretical sufficiency (Charmaz, 2006), which prioritize the depth and relevance of data over the number of participants.

Using the Gioia methodology (Gioia *et al.*, 2013) and following Corbin and Strauss (2014), interview scripts and secondary data, including company Web pages and sustainability reports, were coded. While developing first-order codes closest to the interviewees' words, the content can mostly be seen as either challenges (feeling stuck) or facilitators (can-do attitude). From this, the second order was extracted to capture contents at a more abstract level. This is where we applied the IMP concepts of actors, resources and activities. As shown in Tables 2 and 3, the challenges described by the interviewees indicate a severe lack of both tangible and intangible resources. In contrast, the facilitators highlight potential activities and the role of actors.

Table 1 Interviewees' background

S/N	Organization	Position	Working experience
R1	Municipality A	Electrification strategist	Has been working for six years in project management and R&D, focusing on electric vehicles and charging infrastructure
R2	Municipality A	Management controller	With over five years of experience addressing urban environmental issues, now focuses on electrification and mobility
R3	Municipality A	The director and head of the innovation management division	Worked 15 years in a large OEM company, three years so far in the current position
R4	Municipality A	Project leader in electromobility	Has been working for six years on electromobility and now works on an urban electrification plan
R5	Innovation hub A	Senior project manager in mobility	Worked 10 years related to sustainable transport and energy systems and one year so far in the current position
R6	Innovation hub A	Program manager	Has been working for 10 years in actively initiating and managing projects within electrification, automation and digitalization in the mobility sector
R7	Networking agency A	Expert in E-mobility	Worked in an energy agency for three years and two years in the current position
R8	Networking agency B	Project leader	Has been working for six years on the transition to fossil-free transport by providing expert support to municipalities, regions and companies and facilitating cooperation across municipal and county borders
R9	Main contractor A	Vice innovation president	Over 20 years in the company, mostly involved in enabling financial safety and operations of construction materials
R10	Main contractor A	Project manager	Has been working on an exclusive project to investigate electrifying construction transport for one year when interviewed
R11	Main contractor A	Project developer	Worked for seven years on sustainable development for road and construction regions. Has been working on an exclusive project to investigate electrifying construction transport for one year when interviewed
R12	Main contractor B	Project manager	With over five years of experience addressing urban environmental issues, now focuses on electrification and mobility
R13	Main contractor B	Project manager	Has been working for nine years in the company, mainly responsible for planning stages of construction projects. Participated in some pilot tests of electric machines on-site
R14	Main contractor B	Site manager	Worked 20 years in the company, mainly responsible for the groundwork of construction projects and participated in some pilot tests of electric machines on-site
R15	Main contractor C	Block manager	Was responsible for logistic management in the construction project of a landmark building
R16	Subcontractor A	Individual business owner	Over 10 years in the industry to help construction sites network with providers of construction machines, trucks and materials
R17	Energy company A	Senior project manager for R&D	Worked 19 years in a large OEM company and six years so far for R&D projects related to the electrical grid and electrification of transport
R18	Energy company B	Head of charging infrastructure	Has 15 years of experience in sustainability transformation and one year in the current position

Source(s): Authors' own work

Moving to the third-order themes, we took two small leaps (Langley, 1999): (1) Frame the challenges as "chicken-and-egg" dilemmas, highlighting the interdependence of complementary resources and (2) Recognize the heroism in actors' initiatives, inspired by the daily spirit of "firefighting" in fragmented construction supply chain networks.

4. Results

Figure 2 presents our data structure, supported by representative quotes in Tables 2 and 3. Early on, electrifying construction transport faces many "chicken-and-egg" dilemmas. In adversity, some actors show heroism through initiative, empowerment and resilience. The use of the yin-yang symbol has two metaphors: (1) challenges represent the passive current state (darkness) as described by interviewees, while facilitators highlight potential actions and roles (lightness); (2) achieving a balance between challenges and facilitators is essential for promoting the sustainability transition.

4.1 "Chicken-and-egg" dilemmas

At such an early stage, "chicken-and-egg" dilemmas are pervasive, highlighting the high complexity and uncertainty in driving the transition, as seen in the interconnected issues of limited physical resources, low motivation to implement electrification and lack of knowledge. The atmosphere is captured well by interviewee R10: "Everyone is kind of waiting for everyone in this matter."

4.1.1 Limited physical resources

Technology stands out as the most promising aspect of electrifying construction transport. Electric construction equipment (machines and vehicles) has gained confidence over the years, progressing from handheld and compact machines to

Table 2 Representative quotations: chicken-and-egg dilemmas

"Chicken-and-egg dilemmas"	
Limited physical resources	• "We have tested one machine so far, and it works" (R1) • "In Sweden, do we have any charging infrastructure installed for construction transport so far? No" (R6) • "The power grid is not uniform in the entire country, so you might find places where it's impossible to connect one more excavator; in other places, it has no problem" (R17)
Low motivation in implementing electrification	• "If our client, the company that we are building for, demands it, then we will require it from our subcontractors. However, we don't demand it. Subcontractors are the ones owning the machines; maybe start with them or someone else? not necessarily us, but someone else might need to have the storage of electric machines that we could employ" (R12) • "We do not have any business model for the construction sites that want to go electrified; since the electrified construction sites are still in a very early phase, the situation could change when it becomes more established" (R17) • "Providing a pool of electric vehicles has its uncertainty since we need to make sure they can be rented out at certain times and volumes" (R2) • "Electrical legislation is not prepared for anything; activities like charging a car here and discharging it in another place just don't exist, because you simply don't do that. The electric legislation has to be upgraded and adapted to the new conditions in many areas" (R17)
Insufficient knowledge	• "How can a city issue tenders for installing charging infrastructure, and who is eligible to undertake such projects? How do they engage the market for this, especially considering that, in many cases, the city itself may lack the technical expertise to manage it?" (R4) • "We have this pre-study, looking at sort of the whole scope of electrifying the building logistics, all the transport coming to and from construction sites. If they were to be fully electrified, what sort of impact would that have on both the trucks and the need for charging infrastructure?" (R5) • "Could we do it? How? What? What do consumption profiles look like? Could we combine these so we perhaps could install or connect another customer without increasing the subscription of power?" (R17) • "The knowledge sharing among cities will come a little bit later when we know a little bit more" (R1)

Source(s): Authors' own work

Table 3 Representative quotations: the emergence of "heroes"

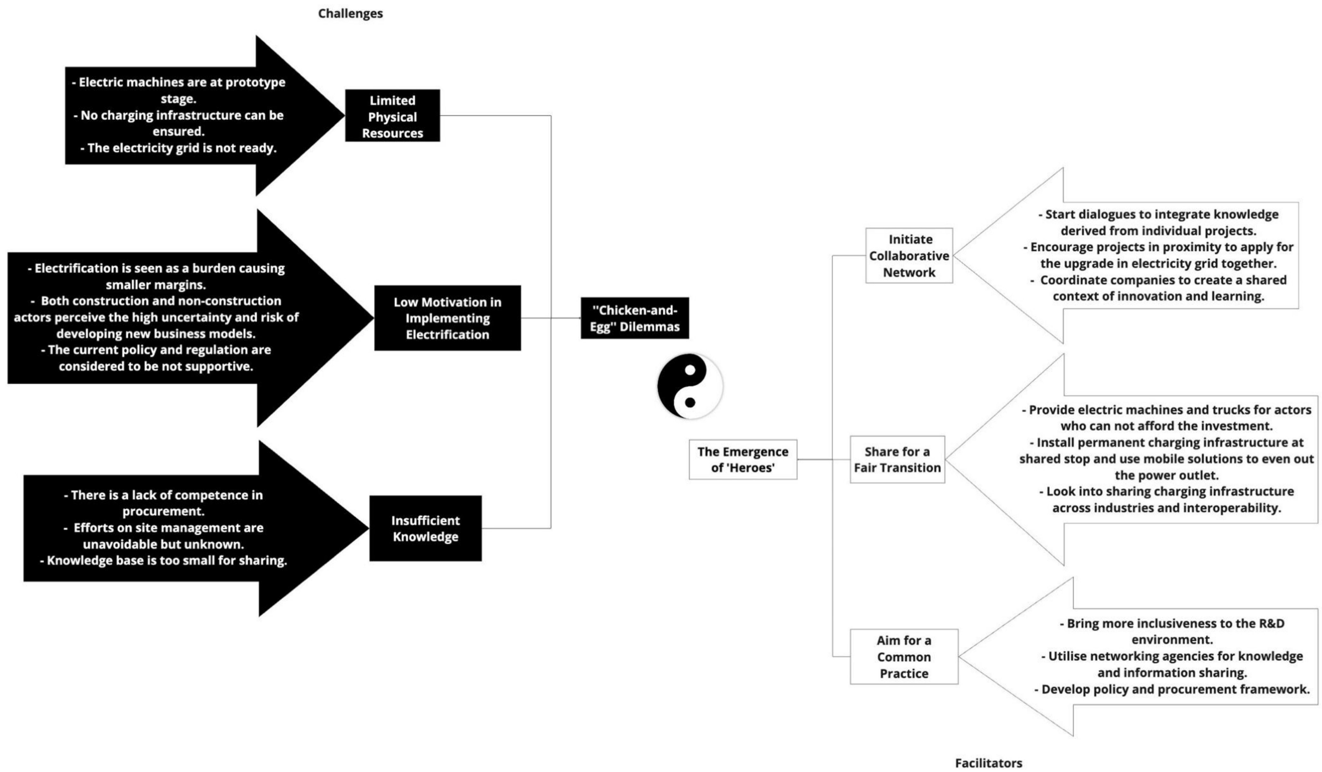
The emergence of "heroes"	
Initiate collaborative network	• "At this stage, we are trying things in collaboration projects. There are different actors who are either new or changing the offerings that they are presenting. They're also sort of finding their roles: am I going to be a direct supplier to a main contractor, or am I going to supply my solutions to a subcontractor?" (R5) • "It's more like an internal network spanning different regions and products, designed to connect customer requests with supplier demand. Once the first project is completed, we will gather the lessons learned, publish them on our internal website, and make this information available to all other projects" (R10) • "Companies that will build in the same area would probably benefit if they work together with all those construction companies and say that, ok, you will all need so much electric power when you build your houses. Let's make a common request to the energy company so that the energy company supplies a lot of power from the start" (R6)
Share for a fair transition	• "If you really want to push toward electrification, you should adopt a product-service system. Instead of paying per hour, you pay per use or per performance of the vehicle or machine. You do not buy the machine outright; instead, you share the risk and the learning with users if the batteries do not perform as expected" (R3) • "So far, most companies are focused on solving their own charging issues. The problem is that, for example, at large logistics hubs, those who act first will secure the available capacity. After a while, there may be no capacity left for others. Companies that are slower to act may get nothing, which might not lead to the most optimal outcome" (R18) • "We address the interoperability and sharing of infrastructure in our electrification plan—for example, between private and public actors, and even with individual users—which is very important. We believe this is the future, but we are not there yet" (R4)
Aim for a common practice	• "Construction companies are not engaging in strategic conversations with us and other governmental agencies. I think they are missing out on funding opportunities for innovation because they are not part of those conversations. They might not feel welcomed when applying for our innovation funding" (R3) • "They say a lot theoretically about how we could do it in the future. But for me, when I'm listening to this seminar, they are not talking about what's happening right now. My new company is exactly working with terminals, but they did not acknowledge that—they don't know what they are speaking about" (R15) • "If it will be a change, yes, but we can't count on incentives anyway. We must look at procurement without them. It's more about the machines being used a lot in the future and having a little bit of money upfront" (R1)

Source(s): Authors' own work

cable-connected heavy equipment. Charging technology is also well advanced, including combined charging system of 350 kW and mobile charging devices. However, relevant products and solutions have not yet been introduced to the market. Currently, only a few electric machines and trucks are running in pilot projects. The equipment is mostly in its prototype stage, and tests are still needed: "We're at the different test sites where we're going to test the whole range of construction equipment. So, it's going to be up from compact machines to 30-ton machines and most of them are going to be battery electric, but the largest ones are also going to be tested with cables" (R5).

With low charging demand and complexity in pilot projects, charging has been seen as a secondary issue so far. When it comes to charging infrastructure, segmenting construction transport is considered essential. For example, on-site and off-site transport usually require different types of charging technologies

Figure 2 Data structure



Source: Authors' own work

(permanent charging stations and mobile charging devices). Because of this unclear definition of charging infrastructure, there is still no dedicated installation for construction transport. The existing ones for private vehicles and other businesses are not suitable for charging construction equipment owing to different routes and charging needs demand: "The energy company has some fast chargers out there that we can use, but it's not optimal to use them if they are not located where our vehicle is parked. Because then you mess up with the working shifts, we cannot drive to a charger that is out of our way" (R4). The capacity of electricity grids will also be an issue as the adoption of electric construction equipment increases.

4.1.2 Low motivation in implementing electrification

To make construction transport sustainable, the suitability of battery-driven electrification remains questionable, while other green fuels are still being considered: "It comes with a lot of downsides; all the electric vehicles on the road still emit particles, and it's not fully sustainable. We cannot just say that, ok, we do everything electrified, and then we're done" (R4). Viewing electrification as just replacing diesel-powered equipment with electric options, leading to higher costs and reduced profits, construction companies (including main contractors and subcontractors) fail to recognize their roles in the transition: "Because we don't own anything, we can't prepare anything. As it is right now, it is all about money. When the customer pays for environmental habituation, we will see a difference" (R16). Faced with uncertain market demand, large buyers, including municipalities, also hesitate to spend their "city maintenance" funds. Although early discussions about the electricity grid are important, no new collaborations are occurring between construction companies and energy firms, who see their role as merely adding new connection points if necessary. Meanwhile, long wait times for electricity grid upgrades under traditional laws continue to block the adoption of new technologies, such as a vehicle-to-grid system.

4.1.3 Insufficient knowledge

The caution in making investments relates to the lack of knowledge about electrification. There is limited competence in preparing tenders because the procurement of charging solutions is new and unclear in the construction industry. The exact total cost is also unknown, as the current price of electric machines can be up to four times higher than that of diesel-driven ones. So far, many operational issues at construction sites remain uninvestigated, as pilot projects have been conducted in well-equipped urban environments, involving only a small number of pieces of electric equipment. After the pilot projects, knowledge is spread in an introverted manner, where different parties bring knowledge back to their organization. When it comes to sharing knowledge among cities, it is admitted that currently, there is not that much knowledge available to be shared at this level.

4.2 The emergence of "heroes"

Facing the challenging initial phase, three groups of heroic actions emerged to facilitate the transition: initiating collaborative networks, sharing for a fair transition and aiming for common practices: "I will say that regardless of what politicians are doing, some companies are still pushing on, and they are even telling politicians that we still need to do this and that" (R7). "When we approached suppliers, as far as they tell us, we are the only ones doing this (aggregating knowledge of electrification), now in Sweden at least. I have the same opinion, and they also appreciate that we take these meetings, have all these questions, and want to accelerate the change of the market" (R10). While the heroic mindset is ubiquitous among the interviewees, the categorization of heroic actions is primarily based on the ongoing practices of the main contractor company, municipal authority and vehicle manufacturer, whom we acknowledge as key contributors to the current transition.

4.2.1 Initiate collaborative networks

While the market situation is frustrating, some actors are exploring their roles positively in different collaborative networks. A pilot project context can be shared for testing solutions on a construction site, from where diverse actors have opportunities to explore their roles and further position themselves in the market. Main contractor A explained that they are working with partners to build an internal Web knowledge-sharing platform. The ambition is related to their vision of electrification: "There is a huge operational efficiency waste that we can take away. The electric machines added to the management system can be much more efficient than one with a combustion engine. It becomes even more interesting for us to use it, which is why we tested this solution of autonomous electrified equipment. I would say that you need to look at it from different angles" (R9). Construction companies in the same area can also aggregate their electricity needs and then apply for an upgrade together.

4.2.2 Share for a fair transition

The construction industry comprises many small subcontractors, including individuals, for whom owning equipment is essential to their livelihood. Considering this, public actors and other big buyers can extend their role beyond mere customers: "I talked to them (Norwegian public procurement) about a fair transition. How and what effect will there be on the electric grid, and how will they change the way it works? But they said that it's up to suppliers and construction companies, so they don't do what we do to try to understand the actors. I feel that they will make the demands, and then someone else will have to do the transition, and they will pay for it" (R1). Public procurement can provide a pool of electric machines and vehicles shared with actors who cannot afford to buy their own. In this scenario, vehicle manufacturers can also play an important role. Some vehicle manufacturers are testing their electric equipment on construction sites. It helps them get valuable input on design preferences from real application contexts and future customers. For construction companies, their pilots are exposed to the new experience of driving electric alternatives, and having electric machines on site is also good for their brand image. Such mutual benefits might be reaped further if sharing risk and learning becomes a business routine: "If you are talking about construction equipment, I don't think that suppliers or manufacturers are willing to sell them. I think that they want to keep them and lease them. So how will that business model develop during the coming years? It is for us together to understand" (R9).

With ongoing competition in grid capacity, sharing charging infrastructure at premises like logistics hubs, which are usually long-standing and can be rented, is feasible. As charging systems become more advanced and standardized, construction machines and vehicles that require fast charging might share chargers with private EVs and other industries: "We have seen that some CPOs (charge point operators) are now changing from, for example, 150–350 kW. They are replacing their old equipment with new ones, and they likely have placed the old equipment in other locations. But at some hot spots where they need to compete with others, they will make sure the charging is as fast as possible" (R18). When it comes to on-site construction transport, mobile charging solutions are more suitable, which can help even out the disturbance in the electricity grid, catering to the temporary project context. Diverse sharing opportunities across different time periods and locations become possible: "The battery storage is movable, so it's rushing here and there to supply the charging. If it is not used anymore, then we move it away. And in the daytime, you can just charge out to those vehicles so you can save money from the different prices of the electric grid" (R7).

4.2.3 Aim for a common practice

The limited attention given to electrifying construction transportation is inconsistent with its significant environmental impact (elephant in the room). There is no well-established environment for research and development in the construction industry. The sector lacks adequate representation in high-level discussions, leading to missed opportunities for securing funding. Small companies often do not have the resources to even apply for available funding. This situation highlights the need for structural changes and increased support to foster a more inclusive and dynamic research and development ecosystem within the construction sector. Knowledge sharing needs to happen more profoundly: "A knowledge maturing that needs to be done to make all actors in the industry realize how they need to shift their operation model; we are doing it, but we could improve" (R3). Without sufficient knowledge sharing, a gap may exist between existing knowledge and areas that require investigation, as noted by R15. A larger-scale procurement of electric equipment and more frequent use of such equipment on-site are considered more essential than merely establishing good incentives. This implies a need for political and regulatory change at a broader level: "I think that Sweden is a very small market. If you look at the whole machinery market in the world, we can't be alone in Sweden to have these incentives and drive the market. What's needed is more on the EU level" (R8).

4.2.4 Strike a balance

Despite the pressing timeline for the sustainability goal, there is a shared recognition that electrification is a complex and long-term challenge. It cannot be achieved through a single effort: "We use the electrical vehicles to transport the last mile delivery; that's good! But do you see the risks? It is somewhat of a greenwash. For the long term, we transport machines and materials on the road that require more effort or charging stations. Installing charging infrastructure on the logistic hub will probably be an intermediate solution; in the long term, we need to look at all the logistics" (R10). Relying on a few pioneering actors to achieve the transition is also risky. The potential to create a cycle of dependency and incapacity can hinder the diffusion of electrification in the market: "We are not waiting; we have our subcontractor within the company, and we are trying to be that company taking the machinery that we need. As long as we can do this in our business team, we are not helping other subcontractors gain experience, and this is due to the subcontractors not only helping us but also helping our competitors, and we don't want that" (R10).

5. Discussion

5.1 Nested chicken-egg dilemmas

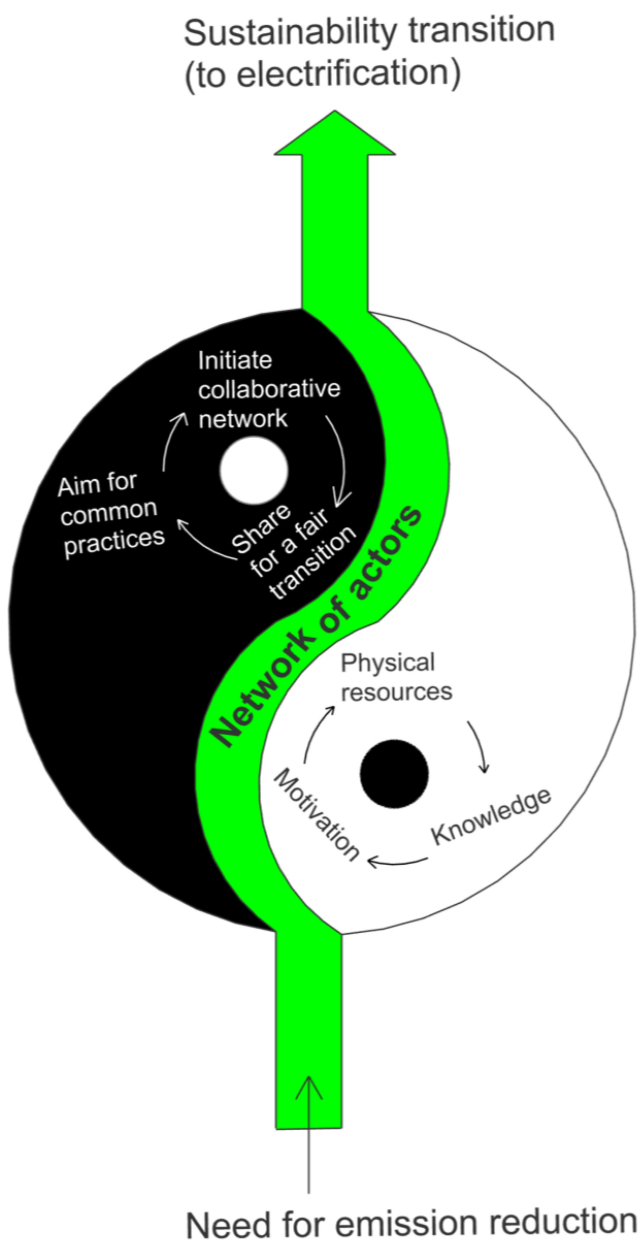
The pressure exerted by the dominant regime (Markard *et al.*, 2012) is gradually increasing at the early stage of the sustainability transition, leading to a long predevelopment phase or a status quo of invisible change (Derks *et al.*, 2022). At this stage, challenges resemble a series of interconnected chicken-and-egg dilemmas, where resolving one issue uncovers or depends on another. The simultaneous shortages of interdependent resources create a self-reinforcing cycle of scarcity, as shown in Figure 3, which explains the slow progress. These critical resources include physical assets (e.g. electric construction equipment, charging infrastructure and electricity supply), motivation for execution (e.g. making investments, developing innovative business models and updating policies and regulations) and knowledge. A well-known example within physical resources is the "electric vehicles versus charging infrastructure" dilemma (Luo *et al.*, 2023; Shi *et al.*, 2021), highlighting the intertwined challenges of building infrastructure while fostering demand for EVs. The high degree of interconnectedness of the complementary resources across supply networks makes the responsibility shift righteous, and no one owns the problem (Martek *et al.*, 2019). The theoretical challenge of spontaneously mobilizing all necessary complementary resources can intensify the perception of the sustainability trilemma (Sconfienza, 2019), as actors view electrification as a trade-off that prioritizes environmental and societal benefits at the expense of their financial profitability.

Thus, we want to highlight "motivation for execution" as a vital resource. This aligns with theories that see corporations as social actors (Westman *et al.*, 2019), raising questions about why some companies engage in social and environmental initiatives while others do not (Brown *et al.*, 2010). Loder *et al.* (2024) further explored motivational factors, suggesting that an organization's perception of transition – whether as an opportunity or a threat – is influenced by its experience with both dominant and alternative technologies, its economic vision, social embeddedness (e.g. supplier networks) and leadership approach.

5.2 Networking for facilitating fair transitions

While collaboration in project-based construction networks remains limited (Dubois *et al.*, 2019), the push for a sustainability transition is placing increasing emphasis on network-level initiatives (Jocevski *et al.*, 2020). This shift is fostering sustainable entrepreneurship and business model innovation (Chaudhary *et al.*, 2023). Faced with resource dilemmas, actors are starting to collaborate across projects, project networks and industrial networks (Wikström *et al.*, 2010). By bringing together actors with complementary resources, activities at different network levels can reinforce and enhance each other, as shown in Figure 3. A similar cyclical process is also seen in the digitalization of the UK architecture, engineering and construction (AEC) industry, where projects serve as mechanisms for knowledge transfer, learning and adoption at the organizational level, influenced by government procurement and standard-setting initiatives (Papachristos *et al.*, 2024). While this approach works well for large incumbents who lead transitions by developing strategies and capabilities across projects, it poses compliance challenges for smaller firms with limited resources, which make up 90% of UK AEC businesses. This issue aligns with the message of "sharing for a fair transition" emphasized by our interviewees, especially in industries dominated by small players who cannot afford high costs alone.

Figure 3 Heroic vision of sustainability transition (to electrification)



Source: Authors' own work

The shift to sustainable construction transport often focuses on environmental and economic sustainability, such as lowering emissions and tackling significant investment costs (Fredriksson and Huge-Brodin, 2022; Sezer and Fredriksson, 2021). However, social sustainability must also be prioritized to ensure that all stakeholders receive benefits, such as equitable access to electrification within a limited electricity grid (Hopkins *et al.*, 2023). An emerging solution is the development of government-led sharing business models, which have shown significant success in promoting electric motor adoption throughout the Asia-Pacific region (Chin *et al.*, 2021). These models can mitigate the sustainability trilemma perceived by individual actors via distributing risks and costs more broadly. For instance, strategically deploying charging infrastructure at diverse locations through collaboration among stakeholders (Melander and Wallström, 2023) can create accessible solutions for all parties. Moreover, such tailored networking activities can promote mutual learning and knowledge exchange (Falcone *et al.*, 2018), thereby speeding up the overall industry transitions. In many practical industries, valuable knowledge arises on-site and matures over time through hands-on experience. Sharing this knowledge across the industry is also a gradual process, especially in loosely connected industries like ACE (Dubois and Gadde, 2002). This highlights the importance of an inclusive research and development environment to enhance the spread of practical knowledge across the sector.

These findings suggest that the role of "heroes" in sustainability transitions is not limited to large firms with the capacity to promote significant change through extensive investments. Instead, it highlights the importance of smaller actors who, despite having limited resources, play a vital role by recognizing resource constraints and initiating strategic actions. These actions may include fostering collaboration with peers, pooling resources and engaging in mutual learning processes – efforts that collectively support systemic change. In fact, this mirrors Sweden's position as a small yet influential market within the global trend toward electrification.

5.3 Beyond acceleration to destination

Faced with resource challenges, actors move forward with long-term views on the transition, even though they are in the early stages. This proactive stance contrasts with typical criticisms of the construction industry for being profit-driven, less adaptable and limited in innovation. In addition to taking initiatives as environmental champions (Garcia *et al.*, 2019), the heroism also manifests in two other ways: by incorporating resilience thinking, networking efforts are aimed at supporting both small and large actors fairly, fostering a collective movement toward sustainability that is just, inclusive and impactful; from a performative perspective, actors seek synergies to reframe "either-or" sustainability dilemmas into "both-and" solutions. This vision of sustainability transitions, as reflected in the electrification of Swedish construction transport, unexpectedly aligns with the yin-yang philosophy, emphasizing harmony and moralism and hierarchy. The philosophy explains why business models in the Asia-Pacific tend to be directed by governments toward solving social issues beyond pure commercial gains (Chin *et al.*, 2021).

Sustainability transitions generally progress through an upward spiral pathway (Geels, 2011), making it crucial to strike a balance between resource dilemmas and activities to ensure continued progress. The continuous nature of these interactions can be represented by the dark spot within the light yang and the light spot within the dark yin – each holding the seed of the other, creating a cycle of renewal and adaptation (Bowker, 2000). Accordingly, in times of resource scarcity, opportunities arise for actors to assume heroic roles. However, as our interviewees express concern, rushing the transition agenda prematurely can lead to outcomes such as greenwashing, dependence on incentives, ruthless market competition and exclusion of smaller players, thereby overshadowing broader progress. Sustainability transitions require moving beyond goal-focused methods toward a shared, meaningful destination shaped by the ongoing interplay of challenges and facilitators. This destination should embody resilient, inclusive change and reconnect with the core purpose of sustainability. We refer to this integrated process and aim as a "heroic vision of sustainability transition" (see Figure 3).

6. Contributions

6.1 Theoretical contribution

This study provides insights that can be applied across different supply chain networks. Using the IMP perspective, the study contributes to SCM theory and the MLP framework (Geels, 2011). It shows how transitions are enabled through inter-organizational collaboration and actor-resource-activity mobilization. By analyzing the early stages of transitions, we view challenges as nested resource dilemmas. These reflect ongoing SCM issues such as resource asymmetries, network complexity and sustainability trade-offs, which are also present in manufacturing and the agri-food industry, as well as in the development of a circular economy. By positioning organizations as social actors (Westman *et al.*, 2019), we identify motivation as a critical resource that enables actors to engage in proactive problem-solving. This is especially critical in networks dominated by hierarchical and contract-based governance, where actors may otherwise be constrained in their ability to collaborate proactively.

We contribute to SCM literature by broadening actor typologies beyond just focal firms or sustainability leaders (Koistinen and Teerikangas, 2021; Pitkänen *et al.*, 2023). We introduce inclusive heroic roles to recognize smaller actors as collaborative facilitators and relational brokers who promote sustainability through networking with a broader vision. This recognition is also relevant for other fragmented networks, such as renewable energy systems. Using the horizontal lens of the IMP perspective, we highlight various collaborative ways to promote sustainability in fragmented, project-based supply chains. Unlike centralized control and efficiency, our findings show that sustainability can develop through decentralized coordination, iterative learning and collective adaptation – especially during transitions marked by uncertainty, such as those involving emerging technologies, local initiatives or sectors without a dominant actor (e.g. logistics and last-mile delivery).

6.2 Managerial and policy implications

This study provides actionable insights by framing sustainability transitions – specifically toward electrification – as a continual balancing act between tackling immediate challenges and pursuing long-term objectives. It urges managers and policymakers to critically evaluate whether the issues they focus on are fundamental, whether their actions are resilient and if the outcomes they aim for are genuinely meaningful. For supply chain managers, this means playing an active role in developing collaborative networks that span multiple projects and organizations. These networks foster knowledge sharing, iterative learning and coordinated efforts. Managers should start conversations with supply chain partners about grid availability to ensure that charging infrastructure is in place, and they should explore cross-industry alliances to share the financial load of electrification investments. Facilitating knowledge exchange across fragmented networks is also essential.

Policymakers play a vital enabling role. Beyond imposing regulatory pressure, policy frameworks should actively promote innovation and provide flexibility for context-specific solutions, especially in complex sectors like construction. To move beyond isolated project results, municipalities must cultivate inherent motivation within organizations and foster inclusivity – ensuring that smaller subcontractors, local authorities and other stakeholders are meaningfully involved in the sustainability transition. To support all supply chain actors in the network during this shift, policymakers should promote a fair transition. One option could be to offer a pool of EVs for leasing, allowing smaller supply chain players to participate in the sustainability movement. Another option might be for government agencies to install charging infrastructure, helping supply chain actors invest in EVs. Policymakers could also create frameworks for public procurement that favor supply chain actors transitioning to more sustainable practices.

7. Conclusions and future research

This study explores challenges and supply chain collaborations in the electrification of onsite and offsite transport within Sweden's construction industry. It combines the MLP on sustainability transitions (Geels, 2011) with the IMP perspective (Gadde *et al.*, 2010) to analyze actor constellations and resource mobilization in supply networks (Huang *et al.*, 2020; Solaimani and van der Veen, 2021). We propose a yin-yang inspired "heroic vision" of sustainability transition, emphasizing balance: actors confront challenges of limited resources, low motivation and insufficient knowledge by fostering collaborative networks, promoting fair transitions and establishing shared practices. The study contributes to SCM literature by linking MLP and IMP perspectives, while acknowledging limitations in focusing on Sweden's construction sector and the early phase of electrification. Future research could examine strategies for scaling up, with sharing economy models offering a promising pathway. In this context, operational optimization tools could play a key role in coordinating resources, improving efficiency and supporting collaborative practices across supply chain networks.

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Appendix

Table A1 Interview guideline is compiled encompassing both preprepared and emergent questions during the conversations

Interview guideline	
Category	**Question**
Introduction and background	• Could you introduce your role and your responsibilities in your organization? • What is your organization's focus regarding electrification in the construction or transportation sectors? • What is the status of electrification efforts in your organization or projects?
Environmental and sustainability goals	• How does electrification contribute to your organization's sustainability targets? • How do you balance the environmental benefits with economic feasibility in your electrification efforts?
Collaboration and actors dynamics	• Are there partnerships or collaborations that have influenced your progress significantly in electrification? • What challenges do you face in coordinating with multiple actors?
Policy, regulations and incentives	• Are there any policies, regulations or standards that support (or hinder) electrification efforts in your industry? • Are there any financial or nonfinancial incentives driving your electrification progress? • What role does your organization play in shaping and complying with regulations?
Technical and infrastructure	• What technical challenges are you encountering (such as grid capacity, charging infrastructure or vehicle/machine compatibility)? • How are you addressing issues like charging needs at construction sites, in different regions like urban vs rural areas? • Have you considered any kinds of innovations (such as mobile charging, battery swapping or shared infrastructure)?
Business models and economic impact	• What are the economic opportunities and risks involved in the progress of electrification? • How do you handle with the costs of electrification? • Have you developed or adopted new business models related to electrification?
Role of small actors	• How do smaller subcontractors and suppliers participate in electrification, and what challenges do they face? • Are there any programs or initiatives in place to support smaller actors in adopting electrification?
Pilot project and knowledge sharing	• How do you document the ongoing electrification projects? • Have you communicated with other cities? • What is the next of the pilot projects? • What support or collaboration do you need to succeed in electrification efforts?
Future trends and closing questions	• What are your thoughts about the future of electrification, such as battery-driven vs hydrogen technologies? • Is there any emerging innovation in technology that you think could accelerate the electrification significantly? • Do you have anything to supplement that we didn't cover?

Source(s): Authors' own work

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