



The electrification of local public transport as a strategic wayfinding process: policy implementation, path dependence, and organizational practices in Italy[☆]

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ABSTRACT

This article examines the electrification of local public transportation in Italy as a complex and uneven organizational transformation, which is an underexplored dimension in existing research. Drawing on nearly four years of qualitative research, the study employs the theoretical lenses of strategic wayfinding and organizational path dependence to analyze how public transportation authorities (PTAs) navigate the transition to electric buses. The findings reveal that electrification is not a linear implementation of policy; rather it is an emergent process shaped by institutional mandates, technological uncertainties, and localized conditions. Rapid changes, driven by top-down regulations and funding logics, often constrain local agency and hamper strategic decision-making. At the same time, the widespread framing of electrification as the ‘one best way’ to greener transportation may restrict technological options and reinforce symbolic pressures. PTAs must respond to evolving battery technologies and infrastructure needs while adapting their strategies to diverse environmental, geographical, and organizational contexts. The study shows how path dependent trajectories both enable and inhibit change, depending on how past investments and practices are interpreted and mobilized. These findings furnish new insights into the organizational dynamics of sustainable mobility transitions, and they underscore the need for multifaceted policies that combine funding with flexible regulation to support rapid technological advances and cross-sector collaboration. Strengthening skills development, aligning strategies with local authorities, and fostering proactive stakeholder engagement are also essential for addressing the diverse challenges of electrification across urban and regional contexts.

1. Introduction

The global push toward sustainable urban development has intensified the focus on transitioning to cleaner and more efficient public transportation systems (Panta et al., 2024). As cities strive to reduce carbon footprints and improve air quality (O’Regan and

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Nyhan, 2023), the electrification of public transportation—particularly through the adoption of electric buses (Borén, 2020; Åslund & Pettersson-Löfstedt, 2023; Tian et al., 2023)—has emerged as a central strategy. This transition is multifaceted. It encompasses environmental, technical, financial, infrastructural (Aldenius et al., 2022; Arizcuren-Blasco et al., 2023; El Hafdaoui et al., 2023; Zhou et al., 2024) and organizational dimensions (Manzoli et al., 2022; Rahman et al., 2024). Comparative studies demonstrate the environmental benefits of electric buses—especially their zero tailpipe emissions—compared with diesel or compressed natural gas vehicles (Lajunen & Lipman, 2016; Gustafsson et al., 2021; Holland et al., 2021; Dulce et al., 2024; Zheng et al., 2024). However, these advantages depend on parallel efforts to decarbonize electricity generation (Correa et al., 2019). Technological advancements have made fleet upgrades increasingly feasible (Zhou et al., 2024), yet financial barriers remain significant. High upfront costs and infrastructure requirements necessitate public subsidies or innovative financing mechanisms (Arizcuren-Blasco et al., 2023). Public acceptance is also essential to foster modal shift and social legitimacy (Tyrinopoulos & Antoniou, 2008; She et al., 2017; Kwon et al., 2020).

1.1. Organizational challenges and governance complexity

While environmental, technical, infrastructural, and financial factors are crucial, they alone cannot fully capture the scope of the transition. The shift to electric fleets entails profound organizational change—an aspect often underexplored in extant research (Bakker & Konings, 2018; Mohammed et al., 2020). Electrification requires aligning business strategies with political and environmental goals, building internal capabilities to manage new technologies, and adapting to evolving infrastructure standards and operational constraints. In addition, PTAs must navigate complex multi-level governance frameworks. This process involves coordinating mandates from European, national, and regional authorities, and engaging stakeholders such as local governments, energy providers, and community representatives. These changes go beyond operational adjustments, and they require the reconfiguration of decision-making processes, the development of cross-sector partnerships, and cultivation of the organizational flexibility needed to deal with shifting regulatory and technological landscapes.

1.2. Research context and methodological focus

To address this underexplored organizational dimension of the electrification process, this article explores how Italian PTAs manage the organizational and institutional challenges of fleet electrification within a decentralized governance context characterized by pronounced regional disparities (Autieri & Cremaschini, 2024). By means of a qualitative longitudinal analysis (April 2020–February 2024), the article traces how PTAs respond to technological uncertainty, regulatory pressures, and local environmental challenges. Italy provides a valuable case for study due to the diversity of its regional approaches, with substantial difference between northern and southern cities. By documenting these dynamics over time, the study develops a processual understanding of electrification as a flexible, learning-based process that reflects the interplay between national mandates and local implementation.

1.3. Theoretical perspective

To interpret the aforementioned dynamics, the study adopts a theoretical framework that combines Chia and Holt's (2009) concept of strategy as 'wayfinding' with a process-oriented view of organizational path dependence (Sydow et al., 2009; Schreyögg & Sydow, 2011). The wayfinding lens emphasizes adaptive, emergent responses to changing conditions rather than linear planning, while path dependence highlights how historical decisions shape and constrain current strategies. Together, these perspectives frame the transition to electric buses as an emergent, non-linear process shaped by institutional pressures, technological uncertainty, and inherited practices.

1.4. Findings and contributions

By adopting this framework, the analysis shows how regulatory directives from European, national, and regional authorities drive a 'forced march' toward sustainability, compelling PTAs to align their strategies with externally imposed goals. While these mandates promote sustainability, they often demand rapid operational adjustments that generate organizational tensions. Moreover, the perception of electrification as the 'one best way' risks discouraging the exploration of alternative solutions that may better address local needs or future technological advancements. At the same time, ongoing uncertainties in battery technology make strategic planning difficult, so that the wayfinding process becomes akin to 'chasing a moving target'. The study underlines the importance of tailoring global sustainability mandates to diverse environmental, geographical, and infrastructural conditions. It also highlights the dual role of path dependence: while previous investments can provide a valuable foundation for electrification, they may also entrench practices that reduce organizational flexibility.

The article's contribution is twofold. Empirically, it offers a comprehensive analysis of Italy's electrification process, illustrating how PTAs navigate diverse regional challenges and fragmented governance structures. The findings show how environmental, financial, and infrastructural differences – particularly between northern and southern regions – shape both the pace and nature of the transition. Theoretically, it conceptualizes the electrification of local public transportation as a strategic wayfinding process shaped by

institutional pressure, technological uncertainty, and historical trajectories. By distinguishing between copying strategies and strategic shaping, the study clarifies how PTAs simultaneously manage short-term constraints and pursue long-term transformation. While grounded in the Italian context, the insights are relevant to other decentralized systems facing similar challenges, and they offer guidance for policymakers and practitioners seeking to align national goals with local realities.

The rest of the article is structured as follows. The next section presents the regulatory and policy framework that drives the transition to electric buses, with a focus on the key regulations and directives from European, national, and regional authorities. Thereafter, the article reviews prior research on the adoption of electric buses in public transportation. It then outlines the theoretical background and methodological approach of the study. The findings section presents the key insights yielded by the analysis. It is followed by the discussion section, where we outline the study's contributions to the literature. In the last section, we draw the conclusions from our analysis, outline its main limitations, and set out its implications for future research.

2. The regulatory and policy framework

2.1. European policy framework for electrification

The transition to electric buses in Europe is guided by a multi-layered institutional framework that has evolved over the past decade. At the European level, key policies like the European Green Deal and the Clean Vehicles Directive (2019/1161/EU) aim to reduce greenhouse gas emissions and promote zero-emission public transport. The Green Deal aims to achieve a 55 % reduction of emissions by 2030 and climate neutrality by 2050. The Clean Vehicles Directive sets progressive targets, requiring 45 % of public bus procurements to meet clean standards by the end of 2025, increasing to 65 % from 2026 to 2030, with half of these vehicles being zero-emission. Supporting measures such as the Alternative Fuels Infrastructure Regulation (AFIR) ensure infrastructure development for electric mobility.

2.2. National strategies and financial commitments

In alignment with these European directives, Italy has introduced national policies to promote the electrification of public transportation. The 2017 guidelines for Sustainable Urban Mobility Plans (Piani Urbani per la Mobilità Sostenibile, PUMS) mandate the adoption of these plans in metropolitan areas and cities with over 100,000 residents, integrating public transport electrification with broader urban and environmental objectives. The National Strategic Plan for Sustainable Mobility, approved in 2019, allocates €3.7 billion over 15 years to bus fleet renewal. This commitment is further bolstered by the National Recovery and Resilience Plan (NRRP), which provides additional funding for electric bus procurement and charging infrastructure.

2.3. Regional initiatives and local adaptation

At the regional level, tailored initiatives address Italy's diverse environmental and infrastructural conditions. For instance, the regional governments of Lombardy and Piedmont have introduced specific targets and funding mechanisms to support electric bus adoption in cities like Milan and Turin. PTAs operating locally must navigate this multi-layered framework while implementing organizational changes to meet these evolving requirements.

2.4. Implications of multi-level governance for PTAs

This multi-level governance framework, combining European, national, and regional directives, presents both opportunities and challenges. On the one hand, it provides essential financial and policy support for electrification projects; on the other, it requires PTAs to align local practices with broader sustainability goals that often necessitate complex coordination across governance levels. This dynamic compels PTAs to balance external pressures with localized solutions, adapting their operations to comply with ambitious climate targets while managing the intricacies of policy implementation.

3. The adoption of electric buses in public transportation

3.1. Environmental benefits and early success cases

Research on the adoption of electric buses in public transportation has grown significantly. It underscores their potential to enhance sustainable urban mobility, as studies have emphasized their environmental benefits, such as reducing air pollution and greenhouse gas emissions (Gustafsson et al., 2021; Holland et al., 2021; Dulce et al., 2024; Zheng et al., 2024). For instance, cities like Shenzhen, China, have demonstrated the substantial environmental gains made possible by the large-scale adoption of electric buses, achieving significant reductions in emissions and noise pollution (Rodrigues & Seixas, 2022). Similarly, case studies on European cities, including Padova, Italy, illustrate how targeted policies and infrastructure investments have facilitated the gradual integration of electric buses, despite challenges related to fleet renewal costs and emission regulations (Andriollo & Tortella, 2015).

3.2. Cost barriers and technical challenges

However, while environmental benefits are well-documented, the transition to electric buses is far from being straightforward, since it involves significant technical, financial, and institutional challenges that vary across regions. For example, research in Canada highlights how differences in institutional frameworks and market conditions have slowed progress with barriers such as high costs and limited infrastructure (Mohamed et al., 2018). By contrast, innovative approaches, such as opportunity-charged and induction-charged buses, demonstrate the feasibility of scaling electric bus operations in dense urban environments (Hassold & Ceder, 2014). Across Europe, Biresseoglu et al. (2018) identify motivators like environmental concerns and policy pressures, but they also emphasize persistent obstacles, including infrastructure costs and technological unpreparedness. One of the main points is the high upfront cost associated with the procurement of electric buses. They require a significant initial investment, mainly due to the cost of batteries and the requisite charging infrastructure. Although operational and maintenance costs for electric buses are generally lower over their lifetimes compared to diesel buses, the high initial costs remain a significant barrier, particularly for cities with constrained budgets (Mohammed et al., 2020).

3.3. The Italian context: fragmented governance and regional disparities

However, Italy presents additional layers of complexity due to its fragmented governance structures and pronounced regional disparities. Institutional inertia and fragmented decision-making processes have hindered the large-scale adoption of electric buses, as Borghetti et al. (2022) illustrate. Coordination challenges between local and national policies exacerbate these delays, creating discrepancies between the more advanced northern regions, such as Lombardy and Piedmont, and the less-resourced southern ones. These disparities highlight the uneven progress of electrification and underscore the need for approaches tailored to regional governance and funding mechanisms.

3.4. Operational and institutional challenges

Operationally, electric bus adoption requires addressing challenges like battery performance, climate impacts, and infrastructure space. Extreme temperatures can reduce battery efficiency, which complicates route planning and scheduling, while dense urban areas face logistical difficulties in accommodating charging infrastructure (Mohammed et al., 2020). Such operational uncertainties underscore the importance of careful planning to ensure reliability and the public acceptance of electric bus services.

Institutional challenges also play a pivotal role in shaping the transition. Rigid regulatory frameworks and entrenched norms often impede progress (Bakker & Konings, 2018), while the lack of coordination between governance levels further exacerbates delays (Borghetti et al., 2022). In other countries, such as Nigeria, research underscores the importance of governmental support in the form of financial incentives and policies to bridge market and infrastructural gaps (Orji, 2024). These examples highlight the critical need for institutional adaptation to overcome barriers and align policies across governance levels.

3.5. Organizational challenges

Recent research has begun to focus also on the organizational practices influencing electric bus adoption. Aldenius et al. (2022) emphasize that the transition is not merely an environmental, technical, or financial challenge; it is also an organizational one that requires significant changes in how local transportation authorities operate and make decisions. These adjustments go beyond operational modifications because they require a comprehensive transformation of organizational structures and practices. Developing new competencies among staff is a critical factor, since PTAs must train personnel to manage advanced technologies, such as battery systems and charging infrastructure, while also ensuring smooth operational transitions. Adapting maintenance practices is equally essential because electric buses introduce technical requirements different from those of traditional diesel fleets, ones that necessitate specialized skills and new protocols. Fostering collaboration with external stakeholders—such as utility companies, policymakers, and bus manufacturers—is of pivotal importance in overcoming the multi-dimensional challenges of electrification. Similarly, Åslund and Petterson-Löfstedt (2023) highlight the role of test and demonstration projects in reducing uncertainties, accumulating technical and operational expertise, and refining strategies for scaling up adoption. Understanding these organizational dynamics is crucial because they can either facilitate or hinder the successful adoption of electric buses. Organizations that proactively engage with these challenges and cultivate adaptive strategies are better positioned to achieve sustainable electrification, whereas those that fail to do so may suffer delays, inefficiencies, and limited progress.

Despite the importance of these aspects, significant gaps persist in knowledge about the organizational processes underpinning this transition. While many studies emphasize external constraints, such as regulatory frameworks and cost barriers, relatively few explore how these pressures translate into internal organizational change. Moreover, existing research often overlooks how evolving technological uncertainties and the complexities of multi-level governance structures impact on organizational practices and decision-making. In addressing these gaps, this study focuses on practices within PTAs in Italy, analyzing how the latter navigate the complex interplay of technological, regulatory, and environmental shifts. By adopting this approach, the article provides critical insights into the internal dynamics of electrification and contributes to a more comprehensive understanding of the importance of

organizational change in sustainable urban mobility transitions.

4. Theoretical framework

The theoretical approach adopted in this article emerged from our initial engagement with the field, which began with exploratory interviews with key stakeholders, including trade associations, unions, and academic experts in transportation, sustainability, and public policy (for more details on the research process, see the Method section). These conversations provided a comprehensive overview of the complex, multifaceted nature of the electrification process in Italy. As we conducted these preliminary interviews, we began to identify recurring patterns in how Italian PTAs were handling the shift to electric buses. These patterns revealed a fluid and ongoing process of adaptation and strategic maneuvering which diverged from standard frameworks that emphasize planned and deliberate strategy-making. Instead, what we observed aligned more closely with Chia and Holt's (2009) concept of 'wayfinding'—an approach to strategizing that is inherently emergent, responsive, and closely connected to the evolving context.

4.1. Strategy emergence as wayfinding

Wayfinding provides a nuanced understanding of strategy as an emergent and adaptive process. This perspective contrasts with standard views that associate effective strategizing with goal-driven planning and deliberate choice. Instead of assuming that coherent action stems from pre-defined objectives and rational calculation, wayfinding emphasizes how organizations navigate uncertainty through practical coping grounded in situated responsiveness and embodied knowledge. Strategic direction, from this perspective, unfolds incrementally, as actors attend to the contingencies and affordances of their environments. Rooted in a practice-based ontology of action (Chia & MacKay, 2007), wayfinding resists the idea that purposeful agency requires explicit planning or representational intent. Rather, it highlights how patterns of effective action can emerge unintentionally from local, embodied engagements with unfolding situations. As such, wayfinding offers an interpretive lens through which to make sense of how organizations act purposefully without necessarily relying on formal plans or articulated strategies—what Chia and Holt (2009, p. 110) describe as an absorbed, non-representational form of agency. In this sense, wayfinding illustrates a mode of strategizing that operates through "absorbed intentionality" and unfolds as a form of "strategy without design." For instance, Chia and Holt (2009, pp. 89–92) discuss how IKEA's global expansion was not the result of a master plan, but instead evolved incrementally through situated responses to specific constraints and opportunities in each national market. Strategic coherence, in this case, emerged retrospectively from locally grounded practices rather than from deliberate design. Particularly relevant to this study is Chia and Holt's discussion of public sector reforms, where top-down plans often meet complex local realities. Chia and Holt (2009, pp. 51–54) show how administrative modernization initiatives—especially in public services—frequently give rise to context-specific interpretations, workarounds, and informal adjustments by frontline staff. These situated practices reshape the implementation process itself, making outcomes emerge from below rather than from central control. This dynamic is especially pertinent to the context of PTAs, where national decarbonization policies interact with entrenched institutional routines, local political agendas, and material constraints.

4.2. Coping strategies and strategic shaping

In our analysis, wayfinding is conceived as a process that unfolds through a continuous tension between coping strategies and strategic shaping. Coping strategies are the reactive measures that organizations adopt to address immediate challenges and constraints as they navigate through uncertain environments. Conversely, strategic shaping involves more proactive efforts, where organizations attempt to influence and steer their environments in directions that better align with their long-term goals. This distinction resonates with the recent description by Chia and Holt (2023) of multiple logics of strategic action (see Table 1).

In particular, our notion of coping aligns with what Chia and Holt describe as a "logic of practice" and a "logic of situation," both of which emphasize absorbed, adaptive, and environmentally responsive forms of action. The idea of shaping, on the other hand, is consistent with what Chia and Holt term a "logic of potential"—an affirmative, experimenting endeavor to open up new trajectories and transform prevailing conditions, without reverting to instrumental planning or control. Rather than treating coping strategies and strategic shaping as separate domains, our analysis suggests that they coexist within the broader wayfinding process, which is best understood as an oscillation between situated responsiveness and transformative initiative. This interplay reflects the ongoing balance

Table 1
Strategic logics and their role in wayfinding.

Logic of action	Strategic orientation	Strategic expression	Role in the wayfinding process
Means-ends logic	Instrumental planning	Strategy as deliberate, plan-based intervention	Outside the wayfinding process
Logic of practice	Grounded in routines and habituated action	Strategy as a pattern emerging from practical coping	Coping (internal routines and practices)
Logic of situation	Attuned to contextual cues and affordances	Strategy as contingent adjustment in unfolding contexts	Coping (external situational sensitivity)
Logic of potential	Oriented to opening possibilities	Strategy as transformative probing and trajectory-setting	Shaping (transformative impulse)

Own elaboration on Chia and Holt (2023).

between responding to environmental pressures and attempting to reshape the conditions in which action unfolds. By focusing on both coping strategies and strategic shaping within the wayfinding framework, we can gain deeper understanding of how organizations navigate complex and fluid environments.

Rather than presenting wayfinding as a normative model or a prescriptive guide to action, we use it as a descriptive and interpretive lens through which to understand how strategy emerges from practical coping and situated responsiveness. At the same time, we claim that emergent forms of action—while often overlooked or underestimated—can, in fact, be highly effective. As Chia & Holt (2009, p. 24) note: “actions that are inconspicuous and may appear peripheral or tangential to the primary concerns of a strategic situation can often turn out to be more efficacious in bringing about desirable and sustainable outcomes”. However, wayfinding should not be understood as a loosely defined or indiscriminate mode of action, as if “everything is wayfinding”. On the contrary, actions that fall within the scope of wayfinding are characterized by practical responsiveness, attunement to unfolding situations, and a form of emergent understanding described as “knowing as we go” (Ingold, 2000, pp. 228–230; Chia & Holt, 2009, p. 164). The distinctive feature of wayfinding is not simply the absence of formal planning; it is also the presence of a coherent responsiveness that unfolds over time and gives rise to patterns of situated agency. For example, a PTA that gradually adapts its charging strategy through local experimentation and sensitivity to infrastructural constraints is engaging in wayfinding. In contrast, strictly replicating national procurement procedures without interpretation, or defaulting to legacy practices out of habit or inertia, would fall outside this logic. Wayfinding is synonymous neither with improvisation nor with unstructured reaction (Chia & Holt, 2009, pp. 163–165); it denotes a particular form of purposeful, context-sensitive navigation that resists both rigid planning and a strategic void.

4.3. Organizational path dependence

The second component of our theoretical framework is the concept of organizational path dependence (Sydow et al., 2009; Schreyögg & Sydow, 2011), which proved increasingly relevant in our analysis because it underscores how past investments, institutional structures, and ingrained practices shape current strategic directions of local transportation organizations. While the standard notion of path dependence traditionally emphasizes the influence of long-term historical developments, we found that even relatively recent decisions – such as early experiments with electric buses and investments in alternative technologies like methane and hydrogen – were able to generate similar self-reinforcing effects. These early commitments often established entrenched operational routines, infrastructure investments, and organizational expertise, creating a path-dependent trajectory that can significantly shape and constrain the strategic options available to PTAs today (Aldenius et al., 2022). The interaction between agency and structure is central to this process, where initial decisions create conditions that favor the continuation of established practices, even when more innovative alternatives become available. For example, past investments in diesel bus fleets or alternative technologies like methane and hydrogen can generate a reluctance to invest in newer electric buses due to concerns about sunk costs or potential disruptions to established maintenance routines. Moreover, organizational routines and the knowledge embedded within these PTAs may create inertia, making it difficult to embrace new technologies that require different skills and approaches. Understanding the mechanisms that drive path dependence therefore requires detailed examination of the social practices, power dynamics, and material conditions that shape organizational decision-making.

Building on these insights, we developed a theoretical framework that integrated Chia and Holt’s concept of strategy emergence as ‘wayfinding’ (Chia & Holt, 2009) with a process-oriented view of organizational path dependence (Sydow et al., 2009; Schreyögg & Sydow, 2011). Within this framework we explored how Italian PTAs navigate the complex landscape of bus fleet electrification, balancing their agency in shaping the future with the constraints and affordances of their technological, institutional, and local environmental contexts, as well as the influence of past decisions. While wayfinding emphasizes the emergent and adaptive nature of strategy, path dependence highlights the enduring impact of historical decisions and established practices. Together, these concepts provide a nuanced lens through which to examine the strategic challenges faced by PTAs, revealing the dynamics that shape the adoption of electric buses in local public transportation systems.

5. Method

5.1. Research scope and case selection

The research reported in this article investigated the transition to electric buses within Italy’s local public transportation sector. The selection of PTAs was determined by the need to capture a diverse range of experiences and insights across different scales of urban and regional contexts. This selection was strategically designed to represent the varying stages and challenges of bus fleet electrification in Italy. The research prioritized key metropolitan areas, such as Milan, Turin, and Genoa, which were identified by employer associations and academic experts as pioneers in the electrification process. These cities were among the first to implement electric buses and faced significant operational and infrastructural challenges. They thus provided valuable insights into the early stages of fleet electrification. Besides these pioneer cities, we included Rome and Naples as the two other main Italian metropolitan areas. Additionally, the research also included medium-scale cities and regional areas such as Cagliari, Bergamo, Bolzano, Brindisi, and other local agencies providing public transportation within the Veneto, Trentino-South Tyrol, Abruzzo, Sardinia, and Emilia-Romagna regions (a comprehensive list of the PTAs included in the study is provided in Appendix 1). These areas were selected to provide a comparative perspective on the adoption of electric buses in different geographical, climatic and administrative contexts. By including cities and regions with varying population sizes, operational scales, orography, and climate conditions, the research aimed to capture the broader spectrum of experiences across Italy – from innovators and early adopters to regions where electrification efforts are still evolving. This

careful selection process ensured that the data collected represented the diverse challenges and strategies encountered across Italy, so that the analysis could draw broader conclusions relevant to the entire country.

5.2. Data collection

Data were gathered from PTAs, bus manufacturing companies, members of trade unions and employer associations, and academic experts. Interviews were conducted with informants from local PTAs such as: CEOs; directors of operations; energy managers; mobility managers; fleet managers; road transport managers; human resource managers; purchasing planning managers; technical and safety directors; heads of innovation; heads of marketing; heads of maintenance; and bus drivers. The research also involved sales managers from bus manufacturing companies, professors of transport engineering and transport economics. A detailed list of the interviews conducted during the study, including the roles of the participants and the dates of each session, is available in [Appendix 2](#).

Fieldwork was conducted between April 2020 and February 2024. It employed a combination of qualitative methods, including semi-structured and in-depth interviews (N = 35), participant observations (N = 1) and document analysis. The extended time span of the field study, covering almost four years, yielded a processual understanding of the changes and strategic processes within the organizations as they navigated the transition to electric buses. By following the same key informants across multiple time points (though not in every organization), the research was able to capture the evolving nature of decision-making processes, the adaptations made in response to emerging challenges, and how these organizations engaged in wayfinding as they adjusted their strategies over time.

5.3. Research process

The research employed a phased approach to data collection, beginning with a first round of interviews with PTAs known to be actively investing in electric buses. Other PTAs were identified using a snowball sampling technique ([Johnson, 2014](#)) relying on referrals from initial respondents to identify other PTAs that were proactive in the electrification of their bus fleet. This approach enabled the research team to map a comprehensive network of PTAs engaged in electrification efforts across Italy. In the subsequent phase, the analysis expanded its focus to include interviews with members of employer associations and trade unions, such as Asstra (Association of Italian Transport Companies), Agens (Agency for Transport), and Uil Trasporti (one of the Italian Transport Workers Unions). Academic experts specializing in transportation, sustainability, and public policy were also consulted during this phase in order to contextualize the findings and enhance understanding of the broader organizational dynamics shaping the transition to electric buses. Additionally, key industrial players in the electric bus market were interviewed, including representatives of major manufacturers such as Daimler, Yutong, Iveco, Byd, Irizar, and Solaris. These companies were selected for their prominent roles in supplying electric buses to the Italian market and their influence on industry standards and technological innovations. Moreover, these interviews provided valuable insights into which PTAs were actively pursuing electrification and which were less engaged in the transition. Finally, a second round of interviews was conducted with PTAs. This phase focused on expanding the scope of the research to include further PTAs, and on revisiting the organizations initially surveyed in order to explore how their strategies and practices had evolved over time. By employing this phased approach, the research acquired a processual understanding of the transition to electric buses, highlighting both the continuity and adaptation of strategies within the rapidly changing landscape of sustainable urban mobility.

5.4. Field engagement: interviews and participant observation

To ensure a comprehensive understanding of the organizational dynamics, a flexible interview approach was adopted. While a consistent interview protocol provided structure, an open-ended format was also used so that participants could describe events and processes in their own words, facilitating a deeper exploration of the topics discussed. This approach was designed to capture the richness and complexity of the experiences shared by the informants ([Patton, 2014](#)). To develop a processual understanding of the organizational dynamics at play, the researchers focused on capturing changes over time ([Abdallah et al., 2019](#)), and particularly on how strategic decisions and operational practices evolved in response to the transition to electric buses. During the interviews, participants were asked to reflect on the unfolding of their experiences and interactions over time (e.g., ‘How did your organization’s strategy shift with the introduction of electric buses?’ ‘Can you describe specific moments when your approach to electrification changed?’). This procedure aimed to elicit detailed narratives that highlighted both the adaptive processes of the organizations and the constraints that they faced.

Each interview lasted between 45 and 125 min. The interviews were recorded and transcribed verbatim, ensuring accuracy in the subsequent analysis. The participant observation session was conducted at the vehicle depot of AMT, Genoa’s PTA, where researchers closely observed daily operations, including the storage, maintenance, and dispatching of both electric and conventional buses. Activities included monitoring how drivers prepared for their shifts, including vehicle checks and route planning. The interactions among drivers, maintenance staff, and managers were noted, particularly how they discussed the performance and maintenance requirements of electric versus conventional buses. Observations also covered the logistical challenges of managing mixed fleets and the infrastructure needed for the charging of electric buses.

5.5. Data analysis

The data were analyzed using template analysis ([King, 2004](#); [King et al., 2018](#)), which was chosen for its flexibility in managing large amounts of qualitative data while allowing for the development of a nuanced understanding of complex processes. The analysis

Table 2
Simplified version of the final template.

1. Navigating technological change	1.1. Adapting to evolving battery technology 1.2. Overcoming infrastructure challenges 1.3. Managing technological uncertainty
2. Institutional pressures and constraints	2.1. Responding to national mandates and funding opportunities 2.2. Regulatory challenges and compliance 2.3. Balancing external expectations with local realities
3. Localized adaptation and strategic choices	3.1. Tailoring strategies to geographical and climatic conditions 3.2. Integration with existing transportation systems 3.3. Strategic decisions in diverse local contexts
4. Organizational path dependence	4.1. Leveraging past experiences with similar technologies 4.2. Challenges of shifting from legacy systems 4.3. Influence of previous strategic decisions on current paths
5. Wayfinding as a strategic process	5.1. Practical coping strategies in response to immediate challenges 5.2. Strategic shaping towards long-term goals 5.3. Continuous adaptation and improvisation

began with the creation of a preliminary coding template based on a priori themes derived from the theoretical framework, such as wayfinding and path dependence. This initial template provided a starting point for coding the data, so that the researchers could categorize text segments related to these themes. As the coding process progressed, the template was iteratively refined to incorporate new themes and insights that emerged from the data. This involved reading through the transcripts multiple times to identify patterns, inconsistencies, and unique aspects of the organizational dynamics related to the adoption of electric buses. Where the data did not fit neatly into the predefined categories, new ones were created, and the template was adjusted accordingly. This iterative process continued until the establishment of a final template which effectively captured the key themes and subthemes that had emerged from the data (see Table 2). The final template was then used to systematically code the entire dataset, ensuring consistency in the analysis while allowing for the exploration of the nuanced interactions between strategic adaptation and path-dependent constraints.

This approach provided a robust framework within which to understand how Italian PTAs navigated the transition to electric buses, highlighting both the adaptive strategies employed and the historical constraints that shaped their decisions. The extended data collection period also allowed the researchers to observe how the strategic processes evolved over time. The following section presents the research findings. It is structured into six subsections that together shed light on the complexities of the electrification process in Italy's PTAs.

6. Findings

6.1. A forced march toward sustainability

The electrification of public transportation fleets in Italy has been largely driven by top-down mandates that compel local PTAs to adopt changes that they might otherwise have approached more gradually. For these organizations, the shift to electric buses is not solely a matter of environmental responsibility; it is also a response to external pressures, including political directives, government regulations, and funding opportunities that favor electric over traditional fuel technologies. As one Director of Operations put it, *'The choices of energy conversion are an external imposition from the political sphere'* (Int. 1), thus highlighting the lack of agency that some organizations feel in this transition. As noted by a Road Transport Manager, this process often begins with directives from local government officials, who mandate the move towards electric buses: *'There was an input from the company's majority shareholder, that is, the mayor of (...), who said electrification... it's not as if the company could choose... the majority shareholder, the owner of the company, said the company must move towards electric buses'* (Int. 22). Financial incentives provided by national policies have also played a crucial role, said a Maintenance, Accounting and Logistics Manager: *'This has been made possible by state funding... which really gave us a flood of money to replace the bus fleet...'* (Int. 32). However, the urgency imposed by funding deadlines created significant challenges, as noted by a Maintenance, Infrastructure and Environment Manager: *'The strict deadlines of the funding forced us to opt for overnight charging (...) because the installing of infrastructure across (...) would require far longer than the few months we had available. It seems almost impossible to us. Getting from now to [completion]... would take a miracle!'* (Int. 21).

This 'forced march' toward electrification, while necessary from an urban sustainability perspective, had raised significant challenges for the organizations considered. They were tasked with managing this complex transition amid technological uncertainties, the need to overhaul existing operational structures, and limited knowledge. As a Fleet Management Manager put it, *'There are many variables that are beyond our control. We are talking about evolving technology, fluctuating regulations, and the unpredictable future of electric mobility. We prepare as best as we can, but we must accept that there will be surprises along the way'* (Int. 34). The regulatory landscape, often slow to adapt to technological advancements, adds another layer of complexity, as stated by a Director of Operations: *'We have a problem with the regulatory system because the technical structures of the Ministry of Transport are not inclined towards innovations; they are more conservative. Every time a new case is proposed, they go into crisis'* (Int. 1).

Despite these challenges, there is a shared understanding among many of these organizations that the path forward is, in essence, a 'point of no return'. As one Innovation Manager said, *'We don't know what the situation will be in six months, but in ten years' time, the number of electric vehicles available will be greater than what we see today. It's a process of no return and it is obligatory'* (Int. 3). This

statement reflects the broader sector-wide recognition that electrification does not merely involve the adoption of new technology; it also entails reshaping the entire operational and strategic landscape within which these agencies function.

6.2. The electric bus as the ‘one best way’ of the green transition

A crucial dimension of the transition to electric buses is the widespread belief that electrification is the ‘one best way’ to advance green public transportation. This view is not necessarily a product of intrinsic organizational preferences. Instead, it is largely shaped by regulatory requirements and external pressures that strongly favor electric technology. For PTAs, the decision to adopt electric buses is often a matter of compliance with regulatory provisions and funding conditions that prioritize electrification over other green alternatives. However, this regulatory emphasis, combined with the symbolic and political appeal of electric buses, has fostered a dominant narrative where electrification is viewed not just as a necessity but as the optimal path to achieving sustainability goals.

National and regional policies, particularly those tied to funding and regulatory incentives, strongly favor the adoption of electric buses. They thus effectively exclude not only traditional internal combustion engines but also more modern Euro 6 diesel vehicles, which have a relatively low environmental impact. This creates some controversy, as highlighted by a Maintenance, Infrastructure and Environment Manager: *‘We already have two-thirds of our fleet as Euro 6, which has very low emissions. However, the transition is almost obligatory because funding is only available for electric or CNG buses’* (Int. 21). The symbolic and political appeal of electric buses also plays a significant role in this perception. As a CEO noted, *‘All the mayors are happy to come wearing their official sashes because they have the electric bus’* (Int. 27). However, the preference for electric buses is not solely the result of external pressures and political symbolism because organizations also engage in thoughtful and rational comparisons among available technologies. Nonetheless, while strategic evaluations often induce organizations to favor electric buses, there are instances where this preference appears less rational and more a product of institutional momentum, as is apparent in the following observation by a Human Resource Manager: *‘We are at a point where, for us, it is clear that the future is electric. Other options are no longer on the table’* (Int. 8).

This focus on electrification, reinforced by institutional frameworks and external incentives, may narrow the strategic vision of PTAs. While the push for electric buses is strong, it may also limit the exploration of other, potentially more suitable, technologies that could better address specific local needs or future technological developments. The risk here is that the dominance of electrification as the preferred technology could lead to an overly narrow approach to sustainable public transportation, one that overlooks more innovative or contextually appropriate solutions.

6.3. Chasing a moving target: the technological uncertainty of the electric bus

One of the most significant challenges that PTAs face in the electrification process is the uncertainty surrounding the technological aspects of electric buses. This uncertainty extends beyond the current capabilities of the technology to encompass future developments and their potential impact on long-term planning and operations. Our research, which spanned four years, provided a unique window into this evolving technological landscape. It enabled us to grasp how these uncertainties shaped and continue to shape the strategic decisions of these organizations. In 2020, when we began our field work, one of the main issues was battery autonomy. At that time, the limited range of electric buses was a significant concern, necessitating the careful planning of charging infrastructure and operational routes. As a Human Resource Manager highlighted, *‘The electric technology is advancing rapidly, but one of the main problems is still the batteries, their lifespan, and the vehicle’s ability to handle longer routes. It will be crucial to teach our drivers a different way to use the accelerator pedal, for instance’* (Int. 8). However, as our more recent data from 2024 reveal, advances in battery technology have dramatically shifted this perspective. Therefore, organizations that were slower to adopt electrification, have begun to see battery autonomy as less of an issue. With some electric buses now achieving a declared range of up to 500 km, the need for intermediate recharging during the day has been significantly reduced, as observed by a Purchasing Planning Manager: *‘With the guaranteed range of 260 to 270 km, there’s no longer a need for additional charging infrastructure along the route or during the day’* (Int. 31). However, in the past, the limited range of early electric buses meant that the organizations that pioneered the electrification project had to invest heavily in charging infrastructure. They had to install charging stations at depots and along bus routes. As an Innovation Manager said: *‘We made large investments in opportunity charging (...) but now opportunity charging must be reconsidered’* (Int. 23), thus highlighting how advances in battery technology are reshaping the infrastructure needs of today’s electric bus fleets.

These advances illustrate the dynamic and cyclical nature of the wayfinding process amid technological uncertainty. By tracking this journey over several years, we saw how PTAs have had to continually adjust their strategies and operations in response to new technological developments. Despite progress, each procurement cycle brings with it a fresh set of challenges, creating a sense of an ‘eternal return’ to unresolved issues. As one Maintenance Manager put it, *‘With this procurement, we can still manage the network with the current infrastructure, but in the future, we will need to address the issue. We are considering network exchanges, but we still need to figure out how to proceed.’* (Int. 7). This highlights how the evolving technology landscape requires PTAs to remain flexible, adapting not only to the latest developments but also revisiting unresolved questions as new complexities arise.

6.4. Global mandates, local challenges: tailoring the electric bus to Italy’s diverse landscapes

The transition to electric buses across Italy has been shaped not only by global and national mandates but also by the unique environmental and geographical conditions of the country’s various regions. These factors necessitate a localized approach to electrification, ensuring that the specific needs and constraints of each area are effectively addressed. One critical factor in this adaptation process is the climate. As a Road Transport Manager highlighted, *‘In the Full Electric (...) one of the things that has a huge impact is the*

climate. Heating consumes as much as traction during the winter months, so what does this mean? It means that in January, the range [of the bus] risks being cut in half. This is different in other parts of the country where the climate is different, right?' (Int. 22). In colder northern regions, the increased energy demands for heating can significantly reduce a bus's range, necessitating more frequent recharging and a potentially more extensive charging infrastructure. In contrast, in warmer southern regions, where heating is less of a concern, buses can operate more efficiently with less energy consumption, allowing for longer routes and reduced infrastructure needs.

Another significant factor is the orography of different regions, particularly in mountainous areas. These regions face unique challenges that affect the performance and efficiency of electric buses, as noted by an Energy Manager: 'For instance, the uphill and downhill sections of our routes require more energy, impacting battery life. Additionally, the infrastructure needed to support electric buses in these areas must be robust enough to handle the terrain' (Int. 28).

These observations underscore the complex interplay between global mandates for electrification and the local challenges raised by Italy's diverse climatic and geographical conditions. The variability in climate and terrain across the country compels PTAs to tailor their electrification strategies to their specific local contexts. In colder regions, this may entail investing in additional charging infrastructure or adopting buses with better insulation or alternative heating solutions, such as the diesel-powered heaters used in some Northern European countries. Conversely, PTAs in warmer regions may focus on optimizing routes for energy efficiency or leveraging milder climates to extend the operational range of their fleets. Thus, while the push toward electric buses is driven by overarching policies, successful implementation requires careful adaptation to Italy's diverse landscapes and climates. This local adaptation is crucial for ensuring that the transition to electric buses is not only environmentally sustainable but also operationally viable in the long term.

6.5. Anchored in history: strategic wayfinding and the double-edged role of path dependence

The journey toward electrification in Italy's local public transportation sector is deeply rooted in early experiments conducted in the late 1990s and early 2000s. Cities like Milan, Turin, Genoa, Bologna, Naples, and Rome were among the pioneers in testing electric bus technologies, being driven to do so by a mix of environmental ambitions and the allure of emerging innovations. However, these early trials were often fraught with challenges. They yielded mixed outcomes that significantly influenced the trajectory of electrification in each city. For example, Turin's early experimentation with electric buses in a park-and-ride scheme near the airport in the early 2000s helped build a stock of knowledge within GTT Torino, facilitating a smoother transition to electric vehicles later on. This positive experience demonstrates how path dependence can ease the adoption of new technologies by leveraging existing knowledge and comfort with similar systems. Similarly, ATM Milano engaged in early experimentation with electric buses, despite the nascent state of the technology and the lack of infrastructure. These initial efforts, while challenging, enabled the organization to build technical expertise and informed its strategic commitment to full electrification years later. Drawing on lessons learned from these early experiments, Milan developed a clear vision for the future of public transportation, leveraging its expertise to become a reference point for other cities in Italy and beyond.

Together, Milan and Turin exemplify how early adoption, despite its difficulties, can be transformed into a strategic advantage. Their leadership in the transition underscores the importance of building on past experiences in order to navigate the complexities of large-scale technological change. However, not all early experiments have led to sustained investment. In Rome, initial trials with electric buses in the city center were plagued by operational issues that fostered skepticism within Rome's ATAC and resulted in a long hiatus in further electrification efforts. Similarly, Naples saw its early experiments with electric buses in pedestrian zones lose momentum, leaving the city with little progress in electrification until external pressures from PUMS (Piano Urbano della Mobilità Sostenibile – Sustainable Urban Mobility Plan) and the NRRP (Italy's National Recovery and Resilience Plan) revived the initiative. These setbacks illustrate the constraining side of path dependence, where early failures or challenges can lead to a prolonged pause in innovation that makes later transitions more difficult. The case of Trentino furnishes another perspective on the double-edged role of path dependence in the electrification process. Beginning in 2019, Trentino Trasporti transitioned its urban fleet to biomethane, leveraging a locally available supply. This strategy was later extended to its extra-urban fleet, which had been predominantly diesel, through the acquisition of methane-powered buses designed to capitalize on the region's biomethane infrastructure. While these earlier green investments demonstrate how past decisions can support current sustainability efforts, they also highlight the constraints of path dependence, because reliance on established technologies may limit flexibility for future transitions, such as the shift to electric buses.

The diverse trajectories of Milan, Turin, Rome, Naples, and Trentino underscore the dual role of path dependence in shaping the electrification of public transportation in Italy. While early adoption and sustained investments allowed Milan and Turin to lead the transition, challenges encountered by cities like Rome and Naples highlight how initial setbacks can delay progress. Trentino's strategic use of biomethane further illustrates the nuanced impact of past decisions, where established technologies can both support sustainability and constrain future flexibility. These contrasting experiences emphasize the importance of leveraging historical knowledge while remaining adaptable to evolving technological and environmental demands.

As a summary of the findings presented above, Table 3 sets out the main organizational responses observed across the PTAs, positioning them along a continuum from reactive coping with institutional and operational constraints to a more proactive strategic shaping of the electrification process. This interpretive model is developed further in the next subsection.

Table 3
Summary of dynamics and trajectories of wayfinding across the cases.

		Key Structural and Institutional Conditions Influencing Organizational Action					
		<i>Institutional and policy pressure</i>	<i>Financial and temporal constraints</i>	<i>Political-symbolic framing of electrification</i>	<i>Fragmented governance and decision-making</i>	<i>Legacy of past decisions and investments</i>	<i>Situated environmental and infrastructural conditions</i>
Emergent Trajectories of Organizational Wayfinding	Coping strategies	PTAs comply directly with top-down mandates, with little internal deliberation, e.g., mayors mandate electrification irrespective of PTA readiness. PTAs modify existing routines and operational processes to conform with regulatory mandates, e.g., adjusting routes and schedules to accommodate new charging regimes. Under regulatory pressure, some PTAs initiate localized pilots that test innovative approaches beyond mere compliance, e.g., localized trials of new charging methods under specific conditions. Some PTAs proactively reinterpret mandates, developing long-term strategies that redefine their approach to electrification. They seek to integrate regulatory demands into a coherent strategic vision, going beyond reactive compliance.	Funding deadlines force immediate, sometimes suboptimal solutions, such as implementing overnight charging due to time constraints. Incremental adjustments in budget allocation and scheduling to meet funding deadlines; fine-tuning operational procedures without radical change. Despite financial constraints, a few PTAs invest in experimental projects to evaluate alternative operational models that might be more efficient in the long run. At a higher strategic level, organizations reallocate resources and redesign business models to overcome short-term constraints, moving from reactive fixes to transformative planning.	Organizations adhere to the dominant narrative—electrification is seen as the only option—without questioning its suitability. Some modifications are made to align with symbolic expectations, such as standardizing the look or performance of the fleet in line with political narratives. In certain cases, local initiatives challenge the dominant framing by testing alternative models or hybrid solutions to electrification. Leaders may question and reframe the politically charged narrative, aiming to carve out alternative paths that offer more sustainable, context-sensitive options.	Fragmented decision-making induces PTAs to adopt the default compliance mode, lacking coordinated responses. Local units attempt to coordinate actions despite fragmented governance, leading to modest, stepwise improvements. Informal experiments emerge at the local level to bypass bureaucratic rigidity, leading to prototype solutions that can be refined over time. Advanced coordination mechanisms and cross-sector collaborations emerge as organizations overcome fragmentation to achieve a unified strategic direction.	Past investments (in diesel or methane) lead to a “lock-in,” constraining innovative responses and favoring mere compliance. Existing legacy systems are gradually upgraded or modified to better integrate electric buses without a complete overhaul. Past experiences are leveraged to experiment with new approaches, e.g., integrating legacy infrastructure with new technology, indicating a move away from strict compliance. Organizations actively overcome past commitments, reframing historical investments as a foundation for a new, transformative trajectory that increases long-term flexibility.	Local infrastructural inadequacies (e.g., insufficient charging points) force reactive adjustments, even if not optimal. Adaptations are made incrementally to account for environmental conditions, e.g., revising route planning to cope with winter-related range reduction. Innovative testing tailored to local conditions—such as experimenting with different scheduling or infrastructural layouts to mitigate climatic effects—characterizes this phase. Strategic plans integrate local environmental data and infrastructural innovations, transforming operational models so that they adapt to diverse and evolving regional conditions.
	<i>Reactive compliance</i>						
	<i>Operational adjustment</i>						
	<i>Situated experimentation</i>						
	Strategic shaping						
	<i>Strategic reframing and transformation</i>						

6.6. Unpacking the wayfinding process: between coping strategies and strategic shaping

The wayfinding process in the electrification of public transportation fleets is not a straightforward path of strategic shaping. Instead, it represents a dynamic interplay between coping strategies and organizational attempts at proactive planning. As PTAs navigate this complex transition, they often find their strategies shaped – and at times constrained – by several contingencies. One key factor is the institutional framework within which they operate. A vivid example of this tension was provided by a Maintenance Manager when talking about the procurement process: *‘We have constructed a project, and we’ve had a lot of freedom in managing every aspect, but unfortunately, the public procurement code doesn’t allow us to reward continuity; each tender becomes a story on its own’* (Int. 7). This reality forces PTAs to adopt coping strategies that align with the institutional framework, even when they might prefer to follow a more cohesive, long-term strategy. This example underscores the broader wayfinding process in which PTAs must continually adapt their strategies to fit with the regulatory and institutional constraints imposed on them.

Another layer of complexity in this wayfinding process is the challenge of overcoming internal resistance to change, particularly in areas where traditional technologies, such as diesel engines, have long been preferred. This resistance is compounded by weaknesses in the local infrastructure, such as the lack of dedicated bus lanes, which can impede the efficiency of electric buses. In regions where these lanes are not available, electric buses may struggle to achieve the same operational efficiency as traditional buses, particularly in dense urban areas where traffic congestion is a significant issue. These infrastructure limitations, combined with concerns about the reliability and maturity of new technologies, contribute to a cautious organizational culture that is hesitant to fully embrace the transition. For instance, a Technical and Safety Manager explained that their electric buses have been out of service for extended periods due to unresolved technical issues: *‘We have two electric buses, but one has been out of service since shortly after it was bought, and even the manufacturer can’t sort out the problem’* (Int. 29). This reflects broader concerns about the readiness of new technologies and the reliability of electric buses in practical, everyday use. This resistance often stems from a broader organizational culture that is cautious about rapid change, particularly when the transition is perceived as being externally driven rather than emerging from within the organization. In certain areas, this can lead to a slower adoption of electrification, as the benefits of new technologies are weighed against the reliability and familiarity of existing systems.

The wayfinding process is also apparent in the dynamic adjustments that PTAs must make in response to rapidly evolving technologies. As seen in the experience of early adopters such as GTT Torino and ATM Milano, the rapid advancement of battery technology has forced PTAs to reconsider their significant investments in opportunity charging, with the more innovative PTAs continually updating their decisions as the technology evolves. Moreover, the strategies adopted demonstrate how the interplay between political influence and the legacy of past strategic decisions shapes current organizational approaches to electrification. For instance, in Trentino, the continuation of investments in methane for extra-urban fleets, alongside the launch of urban electrification, was influenced by both the availability of locally produced biomethane and a cautious stance on hydrogen technology. In contrast, Alto Adige’s focus on hydrogen, although the province has similar geographic conditions, was driven by a mix of political decisions and earlier strategic commitments that included participation in European funding schemes for hydrogen production. This divergence underscores how the combination of past decisions and current political priorities can lead to different technological paths, even in regions with comparable operational challenges.

Ultimately, the wayfinding process in the transition to electric buses has been characterized by the interplay among coping strategies, strategic shaping, and the enduring influence of past decisions intertwined with political pressures. PTAs must navigate the constraints imposed by historical path dependencies, institutional frameworks, and technological uncertainties while striving to shape their strategic direction proactively. This balancing act underscores the complexity of the green transition, where success is determined by the ability of PTAs to adapt to changing circumstances while maintaining a clear vision of their strategic goals.

7. Discussion

This study contributes to the field of public transportation by providing both empirical and theoretical insights into the process of electrifying local bus fleets, particularly in the context of Italy, a major European country with diverse regional characteristics. By analyzing how PTAs navigate the interplay between external pressures, historical trajectories, and emergent strategies, the study highlights the complex organizational dimensions of this transition. Its contributions are twofold, at both the empirical and theoretical levels.

7.1. Regional responses and governance challenges

At the empirical level, the study furnishes a comprehensive account of how Italian PTAs are managing the transition to electric buses. It highlights the critical role of top-down mandates, such as those enforced under Italy’s National Recovery and Resilience Plan, in driving rapid changes within the public transportation sector. This study underscores the varying capacities and responses among different regions, showing how some cities have taken a leading role in the transition, while others are working under significant pressure to catch up. The analysis reveals the practical challenges these organizations face, including the management of technological uncertainties, the adaptation of infrastructure, and the need for solutions tailored to the specific environmental and geographical conditions of each region. By documenting these experiences, the study provides valuable empirical data that can inform future policy-making and the strategic planning of transportation infrastructure and services.

When compared with other national case studies, this one gives additional insights into the challenges and solutions of electrification. For instance, [Aldenius et al. \(2022\)](#) emphasize the role of well-aligned institutional frameworks in Sweden, where local policies

and procurement strategies have facilitated smoother transitions to electric buses. In contrast, the Italian context reveals that fragmented governance and coordination between local and national bodies, as highlighted by [Borghetti et al. \(2022\)](#), can significantly delay the adoption process. This comparison shows that Italy's decentralized institutional structure causes greater disparities in electrification efforts across regions, a dynamic less emphasized in Swedish and Dutch studies like those of [Bakker & Konings \(2018\)](#), where institutional innovation is seen as the key to success. These findings underscore the broader importance of effective coordination across governance levels—local, regional, and national—not only in Italy but in all countries with fragmented governance systems. Addressing such challenges requires a nuanced approach that balances regulatory mandates with flexibility for local adaptation, enabling regions to navigate their unique conditions while maintaining cohesive progress toward overarching sustainability objectives. Moreover, this study builds on [Bireselioglu et al. \(2018\)](#), who discuss barriers such as infrastructure costs and technological readiness across Europe. In Italy, these challenges are compounded by the country's complex regional and local governance structures, which make it more difficult to coordinate efforts and implement a unified electrification strategy. This fragmentation contrasts with the situation in Canada ([Mohammed et al., 2020](#)), where, despite similar technical and financial barriers, PTAs operate in a more streamlined governance context. The fragmented decision-making processes in Italy not only slow down the adoption of electric buses but also lead to uneven development between the country's northern and southern regions, a point that this study highlights in detail.

7.2. Technological, financial, and organizational challenges

The research reported in this article also contributes to understanding the practical implications of technological uncertainty, particularly in the context of battery technology and charging infrastructure. For instance, [Åslund and Pettersson-Löfstedt \(2023\)](#) emphasize that, in Sweden, test and demonstration projects have allowed local authorities to build expertise and reduce uncertainty. In contrast, this study finds that Italian PTAs often lack the same level of proactive engagement with new technologies, which gives rise to a more reactive and compliance-driven approach. This difference underscores the importance of organizational capacity and strategic long-term planning in ensuring a smoother transition to electric buses. In addition to technical challenges, this study also highlights the financial constraints faced by Italian PTAs. [Giagnorio et al. \(2024\)](#) discuss how electrification affects public subsidies, pricing, and welfare in urban areas. Similarly, this study shows how the financial burden of electrification is unevenly distributed across Italian regions, particularly between wealthier northern cities like Milan and Turin and less financially robust southern regions. This insight adds a new layer to the understanding of electrification in Italy, showing how regional disparities influence both financial and operational strategies in the public transportation sector. Finally, this study underscores the importance of tailoring policy and infrastructure solutions to local environmental and geographic conditions, a theme that is underexplored in much of the existing literature. For example, [Andriollo & Tortella \(2015\)](#) highlight the success of Padova's electric bus fleet; a success driven by localized policies and infrastructure investments. This study broadens the scope by comparing different Italian regions, showing that while localized solutions are crucial, national-level coordination is equally necessary to ensure equitable progress across the country. These local variations not only reflect differences in policy and investment, but also point to the deeper organizational shifts required by bus electrification. While the implications may initially resemble those of other technological transitions—such as the need for staff training or new infrastructure—our analysis suggests that electrification entails a more fundamental reconfiguration of organizational practices and temporalities. Unlike previous shifts in fleet technology, electrification demands not only the introduction of new assets and competences, but also a rethinking of how time, space, and operations are coordinated. For instance, charging infrastructure imposes strict temporal constraints that affect route planning, vehicle rotation, and depot usage, thereby reshaping the daily rhythms and routines of work. Moreover, the long-term and uncertain nature of policy incentives, technology standards, and energy costs makes it difficult to rely on stable planning horizons. These factors generate a form of strategic indeterminacy that goes beyond standard organizational adaptations. What is at stake, we argue, is not just a transition in means, but a shift in how local transport organizations configure their strategic and operational decision-making in contexts of enduring uncertainty.

7.3. Strategic wayfinding in practice

At the theoretical level, this study enhances understanding of organizational change as a strategic wayfinding process within the context of public transportation electrification. From this perspective, the study introduces a distinction between coping strategies and strategic shaping which serves to clarify how organizations balance the immediate need to address external pressures with the longer-term objective of shaping their operational and strategic environments. This distinction not only enhances the strategic wayfinding framework but also has practical implications for transportation policy and management. It suggests that effective transition strategies require both reactive and proactive elements: the ability to respond swiftly to regulatory and technological changes, while also guiding the organization towards sustainable and resilient operational models.

[Fig. 1](#) presents the analytical framework of this study, conceptualizing this transition as a strategic wayfinding process. It illustrates the intricate interactions among regulatory mandates, technological uncertainties, and localized conditions that collectively influence the pathways to sustainable urban mobility.

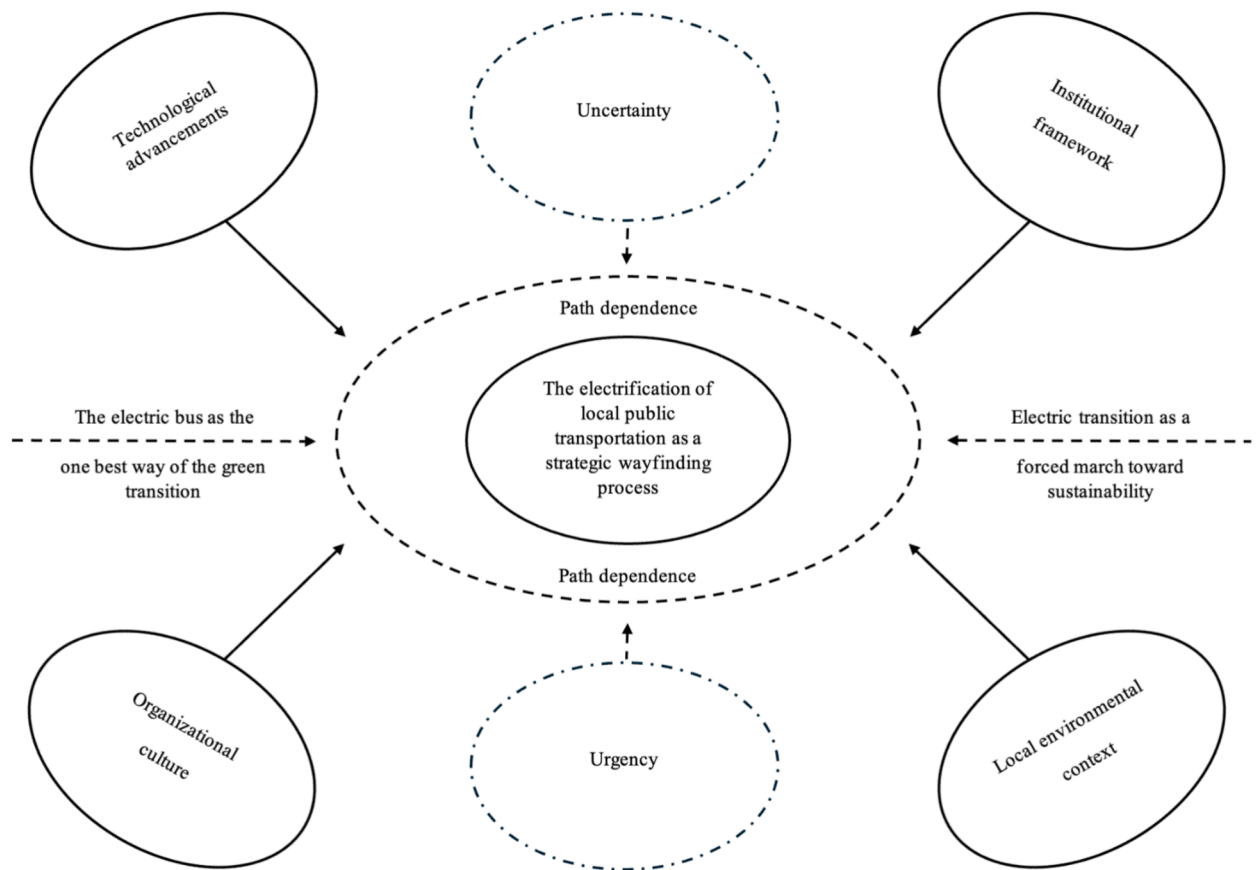


Fig. 1. The electrification of local public transport as a strategic wayfinding process.

7.4. The centrality of path dependence in strategic wayfinding

At the heart of the strategic wayfinding process is the concept of path dependence, which acts as both a guiding and constraining force. This study has illustrated how PTAs' historical decisions, such as early investments in alternative fuel technologies, have established a trajectory that influences current strategic options. For example, organizations that previously invested in biomethane find themselves navigating the electrification process with a pre-existing commitment to alternative fuels. This dual role of path dependence—as both a facilitator and a barrier—is crucial for understanding the uneven progress in electrification across different regions and organizations. However, the relationship between path dependence and strategic action is not linear. While it might be assumed that coping strategies respond to constraining forms of path dependence, and strategic shaping builds on enabling ones, our findings suggest a more complex dynamic. In some cases, PTAs engage in strategic shaping precisely to overcome inherited constraints—for instance, by dismantling legacy infrastructures or reframing prior investments in diesel or biomethane. Conversely, coping strategies may occur even in enabling contexts when PTAs with pre-existing sustainability-oriented routines limit themselves to incremental or compliance-driven actions due to regulatory ambiguity or lack of political support. This more nuanced view positions path dependence not as a static condition, but as something dynamically interpreted and negotiated through different modes of wayfinding. Coping strategies and strategic shaping should thus be understood not as opposites, but as interdependent responses to evolving constraints and possibilities shaped by past decisions.

7.5. The role of technological advancements and uncertainty

The dynamic relationship between technological advancements and uncertainty is another key aspect. The rapid evolution of battery technology exemplifies how PTAs must continuously adjust their strategies in response to new developments. This ongoing adaptation process, akin to 'chasing a moving target', highlights the need for flexibility in strategic planning, where organizations must remain responsive to technological shifts while managing the risks associated with untested systems.

7.6. Institutional framework and the perception of the electric bus as the 'one best way'

Institutional frameworks exert significant external pressure, thereby shaping the strategic direction of PTAs. These frameworks, including national mandates like Italy's National Recovery and Resilience Plan (NRRP), compel organizations to prioritize electrification. This forced march toward sustainability often requires PTAs to make rapid decisions to comply with regulatory deadlines. Additionally, the framework reveals how the electric bus has been posited as the 'one best way' to achieve green public transportation, potentially stifling innovation and limiting the exploration of alternative technologies.

7.7. Local environmental context and organizational culture

The analytical framework proposed by this article also emphasizes the importance of local environmental contexts and organizational culture in shaping the electrification process. These factors necessitate a tailored approach to implementing global mandates, ensuring that strategies are adapted to the specific climatic, geographical, and infrastructural conditions of each region. Organizational culture plays a crucial role in either facilitating or hampering the transition to electric buses. In some PTAs, a culture of innovation supports the adoption of electrification, while in others, resistance to change hinders progress.

7.8. The interplay between urgency and strategic shaping

Finally, the framework illustrates the tension between urgency and the need for strategic shaping. The pressure to meet tight deadlines imposed by funding mechanisms and regulatory mandates forces PTAs to focus on short-term coping strategies. However, the concept of strategic shaping suggests that PTAs are not merely passive recipients of external pressures but actively engage in shaping their strategic environments. This proactive element is essential for navigating the complexities of the electrification process.

In sum, by focusing on the Italian context, this study provides a nuanced understanding of the complex interplay among external pressures, historical legacies, and emergent strategies in the electrification of public transportation. Rather than viewing electrification as solely a technical or policy-driven initiative, the findings position it as a multifaceted organizational transformation shaped by institutional frameworks and localized dynamics. The research reported in this article reveals how path-dependent practices intersect with technological and financial constraints to influence PTAs' ability to adapt and innovate. These insights have valuable implications for countries with decentralized governance systems, where effective coordination across local, regional, and national policies is essential for driving sustainable transitions. By shedding light on these dynamics, the study highlights pathways to balancing regulatory compliance with adaptive strategies that address the unique conditions of each region.

8. Conclusion

This article has explored the transition to electric buses within Italy's local public transportation systems, and it has employed the concepts of strategic wayfinding and path dependence to analyze this adaptive process. The findings highlight how electrification emerges as a dynamic transformation shaped by historical decisions, institutional mandates, and technological advancements. PTAs must navigate these interconnected forces, balancing immediate regulatory demands with longer-term strategies tailored to their specific contexts. By examining these emergent strategies, the study underscores the importance of flexibility and context-sensitive approaches that accommodate diverse local conditions while avoiding overly rigid or unidirectional pathways to sustainability.

In addressing these challenges, several policy recommendations arise. As noted by Miles and Potter (2014), innovation diffusion often requires more than subsidies alone; it demands new risk management strategies and organizational structures. The insights from this qualitative analysis of Italian PTAs reveal key organizational and structural barriers to transitioning toward electric fleets. Besides the provision of funds, this transition requires strategic coordination, especially around issues such as timing, skills training, coordination with urban institutions, and integrating multiple sustainability solutions, including alternative engines and fuels. A critical issue identified is the rapid pace of regulatory change, which, while necessary to meet sustainability targets, strains PTAs' ability to activate in-house skills and foster collaborative learning within their organizations. Viewing the electric bus as merely the endpoint of this complex process risks omitting critical intermediate steps, such as urban planning adjustments, community engagement, and necessary infrastructural updates. Effective transition strategies must account for an ecosystem of interconnected changes, including the coexistence of multiple technologies and innovative financing models that support a flexible transition.

This study has also emphasized the need for PTAs to collaborate more closely with local authorities, energy suppliers, and urban community representatives. Such partnerships are essential for developing adaptable fleet conversion timelines that address not only the technical and financial aspects of electrification but also its broader urban and social implications. Local public transport associations can play a pivotal role in promoting coordination and knowledge-sharing across the sector, aligning the needs of transportation providers with public authority mandates, and creating a rich dataset with which to guide future decisions on costs and vehicle performance. Additionally, the rapid pace of technological advancement in areas such as synthetic fuels, engine design, and mobility tools underscores the need for regulatory flexibility. Rigid regulations that mandate a single pathway may inadvertently stifle innovation and prevent PTAs from experimenting with alternative solutions that might better suit local needs or future technological developments. Indeed, whilst electrification represents a pivotal strategy for sustainable public transport, alternative low-emission technologies such as advanced diesel (Euro 6), compressed natural gas (CNG), and hydrogen fuel cells continue to play a significant role. Diesel buses, despite higher emissions, offer lower initial costs, and they benefit from well-established infrastructure; CNG provides a transitional solution with moderate emission reductions, whereas hydrogen—despite its potential for long-range

transport—faces significant barriers related to cost and refueling infrastructure. Battery-electric buses, while offering zero tailpipe emissions, they require substantial investment in charging infrastructure and grid upgrades, thereby placing considerable strain on public budgets. Moreover, their performance is sensitive to climatic and topographical conditions, which can impact operational efficiency. A substantial body of research has compared the costs and trade-offs among these options (e.g. [Dahlgren and Ammenberg, 2021](#); [Muñoz et al., 2022](#); [Razy-Yanuv and Meron, 2024](#)).

A rapid transition to full electrification should not lead to the neglect of these alternatives. Instead, it calls for a diversified and context-sensitive approach—one that carefully considers cost, technological maturity, and operational feasibility across regions. A more gradual transition could enable PTAs to benefit from future technological advancements and avoid premature infrastructure lock-ins, especially given the strong cost fluctuations expected in the electric bus market over the coming years ([Borghetti et al., 2022](#)).

While this study provides valuable insights into the organizational dynamics of electrification, it also has limitations that open avenues for future research. Focusing on Italian PTAs, this analysis has offered an illustrative perspective, but it may not have fully captured the diversity of challenges faced by PTAs in different contexts. Future research could extend this analysis to other regions, examining how different institutional frameworks and historical trajectories influence the adoption of sustainable technologies. Expanding this research to include the broader ecosystem of actors involved in the transition—such as policymakers, manufacturers, and civil society—could further illuminate the multi-level dynamics that shape electrification efforts. Furthermore, the theoretical approach adopted here offers a lens that could be used to examine other contexts of technological transition, revealing how organizations adapt within evolving technological and institutional landscapes.

In sum, the findings of this study underscore the importance of a nuanced, adaptive approach to public transportation electrification, where policy, organizational strategy, and collaborative frameworks converge to support sustainable urban mobility. By situating the Italian experience within a broader framework of strategic wayfinding, this study offers a model with which to understand similar transitions globally, emphasizing that electrification is not a static goal but a dynamic, evolving process requiring coordinated and context-aware strategies.

CRedit authorship contribution statement

Angelo Gasparre: Writing – review & editing, Formal analysis, Investigation, Writing – original draft, Data curation, Methodology, Conceptualization. **Claudia Burlando:** Investigation, Methodology, Conceptualization, Writing – review & editing, Formal analysis, Writing – original draft, Data curation. **Tiziano Pavanini:** Methodology, Conceptualization, Writing – original draft, Data curation, Investigation, Writing – review & editing, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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