Incumbent actors, guided search paths, and landmark projects in infra-system transitions: Re-thinking Strategic Niche Management with a case study of French tramway diffusion (1971-2016)

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Abstract
Focusing on the emergence and diffusion of radical innovations, we confront the typical understanding in the Strategic Niche Management framework with an in-depth longitudinal case study of French modern tramways (1971-2016), which represents a particular technology class: local infrastructure systems. The case confirms the relevance of existing SNM-concepts, but also points to three deviations, which we reformulate as conceptual differentiations: 1) incumbent actors from neighbouring regimes (rather than small start-ups or grassroots activists) were crucial for developing the innovation, 2) early visions were coherent and specific (rather than diffuse), which led to guided search paths (rather than open-ended tinkering), and 3) single 'landmark projects' decisively accelerated developments. Exploring a greater variety of diffusion and transition patterns (based on temporal interactions of causal mechanisms and varying roles played by different actors) is a fruitful way forward for sustainability transitions research.

Keywords
Socio-technical transitions; local infrastructure systems; landmark projects; tramways; Strategic Niche Management

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1 Introduction

This paper aims to contribute to debates on the emergence and diffusion of radical innovations in the literature on sustainability transitions. In a nutshell, the archetypical understanding of this topic in the Strategic Niche Management (SNM) framework (Hoogma et al., 2002; Kemp et al., 1998; Schot and Geels, 2008) and the Multi-Level Perspective (MLP) (Elzen et al., 2004; Geels et al., 2017) is that that radical innovations (which are defined as deviating in multiple dimensions from the existing regime) initially emerge in sheltered niches that constitute protected spaces (Smith and Raven, 2012), where new entrants and outsiders can experiment and learn on multiple dimensions (Van De Poel, 2000). This is then followed by gradual diffusion into larger market niches, which involves uphill struggles against existing systems, which are defended by powerful incumbent actors (Geels, 2014) and stabilised by entrenched rules and institutions, called 'socio-technical regimes'. Broad diffusion into mainstream markets is therefore thought to require pressure(s) from exogenous 'landscape' developments, which destabilise entrenched regimes and create windows of opportunity for niche-innovations (Geels, 2002). This archetypical understanding has been empirically validated with many historical and contemporary studies.

In recent years, however, scholars have started to nuance or criticise parts of this archetypical conceptualisation, often drawing on revealing single cases. Recent SNM-work, for instance, emphasises that existing regimes face pressures not only from exogenous landscape developments, but also from externally-oriented activities of niche-actors. Drawing on cases from renewable electricity technologies, scholars (Kern et al., 2015; Raven et al.,

2016; Smith and Raven, 2012; Verhees et al., 2013) have identified various 'empowerment' activities (e.g. lobbying, coalition building, discursive framing) that aim to change regime-level selection environments (e.g. regulations, incentives) and thus facilitate the diffusion of niche-innovations. While developing important nuances, these 'empowerment' studies privilege the perspective of niche advocates and thus adopt a 'bottom-up' or niche-to-regime view on change that remains close to the archetypical understanding.

Other scholars (Bergek et al., 2013; Berggren et al., 2015; Penna and Geels, 2015) have criticised the emphasis on new entrants, outsiders or grassroots activists as developers of radical innovations. Drawing on case studies from various capital-intensive industries (automotive, gas turbines, heavy goods vehicles), they show that incumbent actors need not be completely locked-in to existing regimes and can strategically hedge or diversify towards niche-innovations. New trajectories may thus also arise from 'top-down' or regime-to-niche engagement processes.

This paper aims to contribute to this trend of criticising and nuancing (parts of) the archetypical understanding, using revealing cases. Our specific case study is the emergence and diffusion of modern tramway systems in France (1971-2016), which belongs to a particular class of technology: large, but localised infrastructural systems. Other examples of this technology class include district heating systems, integrated waste management systems, and dedicated cycling infrastructures. One characteristic of these technologies is that, like large technical systems (LTS) in the Hughes's tradition, they have an infrastructural component, which means they are inherently capital-intensive, complex, often custom-built, politically-loaded, and highly visible during construction (Markard, 2011). But whereas LTS are usually (inter)nationally integrated, a second characteristic is that these infra-systems remain localised, which also means that urban actors tend to be substantially involved in emergence and diffusion processes. These characteristics means that tram systems deviate from the discrete artefacts that are commonly studied in the sustainability transitions literature, e.g. solar cells (Verhees et al., 2013), wind turbines (Kern et al., 2015), electric vehicles (Bergek et al., 2013), heat pumps (Bergman, 2012). Using the specificities of our case, we aim to make three specific contributions that amend (parts of) the archetypical understanding, discussed above.

First, while the SNM literature emphasises the role of new entrants and relative outsiders (Smith and Raven, 2012; Van De Poel, 2000), we suggest that this risks overlooking the role of incumbent actors in niche development. While the potential relevance of incumbent actors has been noted before, our tram case specifically points to the role of *incumbent actors from neighbouring regimes* (railways, urban planning), supported by a national technical bureaucracy, and to their *early involvement* (which differs from usual consideration of their relevance to later up-scaling).

Second, while the SNM-literature emphasises diffuse visions and open-ended experimentation and tinkering in early phases (Kemp et al., 1998; Schot and Geels, 2008), our case shows that the emergence of French trams was inspired by a relatively *coherent and specific vision* (which positioned trams as modern urban transport alternative to the auto-mobility regime), which was translated into a highly *guided search path*. This specificity relates to the actor coalition (including incumbent organisations and a hands-on approach to state-led industrial strategy) and to characteristics of infrastructural systems (large, capital-intensive) that limit the scope for small-scale trials and subsequent up-scaling.

Third, we propose that *single (landmark) projects* may have transformative effects that markedly influence emergence and diffusion processes. Although early SNM-studies emphasised the role of single experiments and demonstration projects (Kemp et al. 1998), later work rowed back on this (Hoogma et al., 2002), leading to a subsequent focus on sequences of projects and their role in niche development (Geels and Deuten, 2006; Raven et al., 2008; Schot and Geels, 2008). While project sequencing is indeed important, we suggest that the potential importance of individual projects may have been lost, especially for local

infrastructural systems, which are often highly visible during construction and require the mobilisation of substantial political and financial resources.

The paper is structured as follows. Section 2 discusses Strategic Niche Management and positions our three contributions in the wider literature. Section 3 addresses methodological considerations. Section 4 provides an in-depth longitudinal analysis of the development and diffusion of modern tramways in France (1971-2016).[1] Section 5 discusses the results and our conceptual elaborations. Section 6 concludes.

2 Conceptual framework and positioning our contributions

Strategic Niche Management (SNM) and the Multi-Level Perspective (MLP) are two prominent and complementary frameworks in the sustainability transitions literature (Markard et al., 2012). Section 2.1 briefly reviews their conceptualisation of the emergence and diffusion of radical innovations. Section 2.2 then positions our case-specific contributions in the literature by identifying some conceptual gaps. Because of our interest in radical innovations, the discussion mostly focuses on SNM, which is complemented by MLP-insights.

2.1 Extant literature

Because radical innovations initially emerge as 'hopeful monstrosities' (Mokyr, 1990), they cannot immediately compete with deeply entrenched systems in mainstream selection environments.[2] Drawing on evolutionary theory, the SNM literature therefore proposes that radical innovations initially emerge in peripheral niches with different selection criteria, which provide 'protected spaces' that shield innovations from mainstream pressures (Schot and Geels, 2008). Drawing additionally on the sociology of technology, early SNM-scholars (Hoogma et al., 2002; Kemp et al., 1998; Schot et al., 1994) suggested that niches provide space for three developmental processes: a) *learning* processes and knowledge accumulation, b) the articulation of shared *visions and expectations*, and c) the building of *social networks and advocacy coalitions*.

These early SNM-scholars also emphasised the role of individual projects as material sites for learning processes, developing collaborations and refining expectations. But, based on studies of electric vehicle projects in various countries, Hoogma et al. (2002:195) rowed back on this, concluding that: "We were certainly over-optimistic about the potential of SNM as a tool for transition (...) The positive circles of feedback by which a technology comes into its own and escapes a technological niche are far weaker than expected and appear to take far longer than expected (5 years or more). (…) The experiments did not make actor change their strategies and invest in the further major development of a technology. (…) The contributions of the projects to niche development appears to be small."

Subsequent contributions distinguished between two analytical levels: concrete local projects and a 'global' field-level, which refers to an emerging community with shared rules and agendas (Geels and Deuten, 2006; Geels and Raven, 2006; Raven et al., 2008; Schot and Geels, 2008). This distinction enabled niche development to be conceptualised as *sequences*

[1] Tram-systems were not 'new to the world' in the 1970s. They were prominent in the early 20th century, but then eroded because of declining investments and services, leading to complete disappearance from French cities (1950s-1960s) to make way for motorised transport. When 'modern trams' appeared in the 1970s, they were a radical innovation compared to the dominant auto-mobility regime, and included significant innovations that distinguished them from historic trams. This re-interpretation of an old technology is also an interesting case characteristic, which we do not elaborate in this paper.

[2] The 'hopeful monstrosity' framing is less pertinent for the revival of old technologies like trams, but the points of limited competitiveness and need for initial protection remain valid.

of projects that stimulate successive rounds of learning, network, building and visioning (Figure 1).

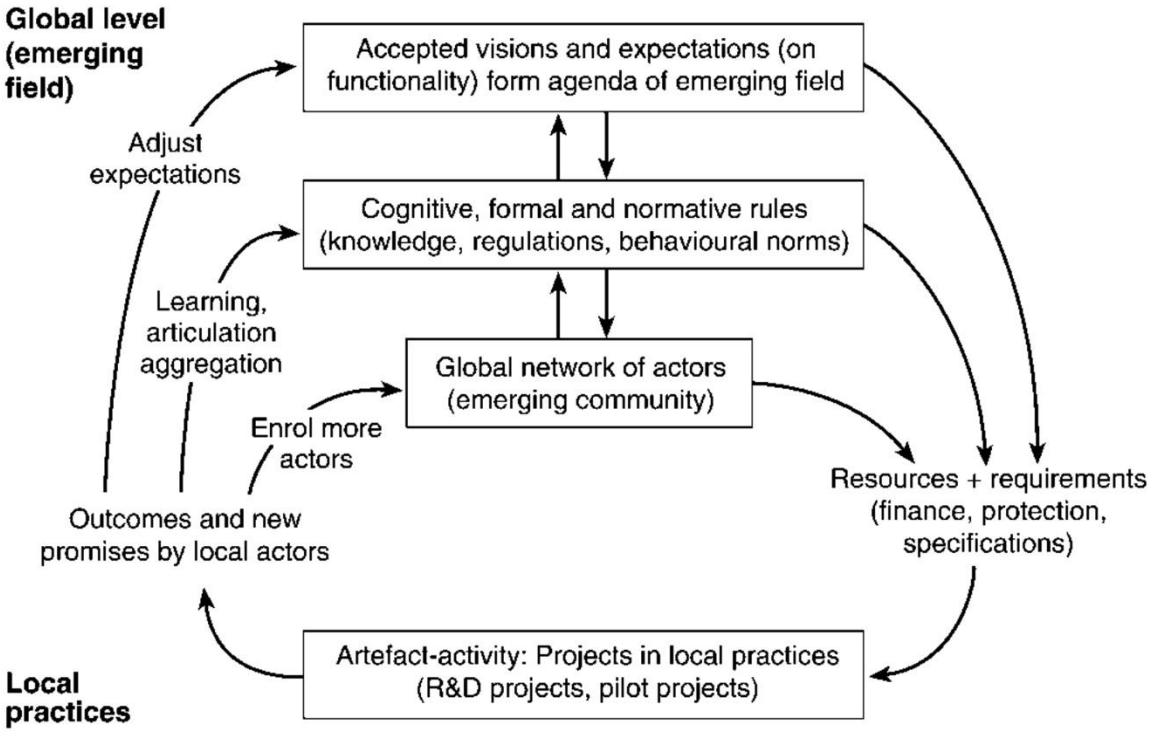

Figure 1: The dynamics of niche development trajectories (Geels and Raven, 2006:379)

Early projects tend to be weakly articulated, exploratory in nature, and directionally diffuse, because field-level rules and institutions are initially fuzzy. Sequences of projects may give rise to the circulation of experiences and dedicated aggregation and generalisation activities, aimed at articulating best practices, technical models and search heuristics (Geels and Raven, 2006). Consequently, "Sequences of local projects may gradually add up to an emerging field (niche) at the global level […] If learning processes in local projects are compared and aggregated, the cognitive rules at the more global niche level may gradually become more articulated, specific and stable" (Schot and Geels, 2008:543).

While early SNM-contributions focused on the *emergence* of radical innovations (Kemp et al., 1998; Hoogma et al., 2002), recent work has started to address *diffusion*, investigating how innovations can "escape their protective spaces" (Smith and Raven, 2012:1026). In MLP-terminology, diffusion requires niche-innovations to interact with existing socio-technical systems and regimes, which include established industry structures, dominant technologies and infrastructures, mainstream markets and user practices, existing policies and power structures, and socio-cultural frames (Rip and Kemp, 1998; Geels, 2002). Diffusion analysis therefore requires attention to both niche-internal processes and external contexts.

The MLP traditionally emphasises the role of external 'landscape' pressures in destabilising existing regimes, which then provides windows of opportunity for the further diffusion of niche-innovations. Complementing this view, recent SNM-work suggests that existing regimes also face pressures from externally-oriented activities by niche-actors. Smith and Raven (2012), for instance, highlighted the importance of 'empowerment', i.e. activities through which niche advocates aim to bring about changes in the rules and selection criteria of broader socio-technical regimes. Empowerment is an inherently political and negotiated process involving the building of coalitions and the deployment of narratives that justify further niche support policies or changes in regime rules (Boon et al.,

2014; Kern et al., 2015; Smith and Raven, 2012; Verhees et al., 2013). Empowerment activities may aim to a) increase the competitiveness of innovations under existing rules ('fit-and-conform' pattern), for instance through sustained R&D support, or b) focus on changing broader selection criteria (leading to a 'stretch-and-transform' pattern), for instance through institutional changes in regulations or incentives.

While this 'empowerment' research has usefully highlighted the activities through which niche-actors aim to influence existing regimes, it continues to privilege a 'bottom-up' view of change. A similar orientation characterises recent research on niche-regime interactions. Diaz et al. (2013), for instance, showed how niche-actors can increase resource availability through strategic enrolment of incumbent actors. Ingram et al. (2015) identified interaction processes (such as certification and network building) that can help translate local niche-findings into wider regimes. But Smink et al. (2015) showed that collaborations between new entrants and incumbents may be hindered by dominant institutional logics and that boundary spanners can fulfil bridging roles.

2.2 Conceptual elaborations

To position our case-specific contributions in this literature, we articulate three criticisms and suggest conceptual elaborations. A first criticism is that research on niche-innovations and niche-regime interactions predominantly conceptualises emergence and diffusion as a 'bottom-up' process, in which new entrants and outsiders challenge the dominant position of incumbent actors and regimes. To overcome this one-sidedness, a more symmetrical analysis of niche-regime interactions is needed, which also accommodates the possible role of incumbent actors in niche development. Recent studies of capital-intensive industries show that incumbent actors can reorient towards radical niche-innovations through 'creative accumulation' of capabilities (Bergek et al., 2013) integrated portfolio strategies (Berggren et al., 2015) or hedging and gradual diversification (Penna and Geels, 2015). Building on this and drawing on the French tram study, our first contribution is to propose that incumbent actors *from neighbouring regimes* (e.g. railways, urban planning) may play important roles in niche development, both at early stages and in later diffusion. This contribution thus goes beyond the Schumpeterian dichotomy (either new entrants or incumbents driving change), which continues to dominate the transition literature (also in the recent contributions, discussed above).

A second criticism is that SNM-studies tend to over-emphasise one kind of pattern for emerging innovations, in which broad and diffuse visions are initially explored with a diversity of search and tinkering processes; the resulting learning processes subsequently lead to narrowing down, commitment to one trajectory, and greater specificity in visions (Kemp et al., 1998; Schot and Geels, 2008). This emphasis on initial variety and diffuse directionality relates to SNM's roots in evolutionary theory. But, drawing on our case, we propose that radical innovations may also emerge from highly specific visions, which give rise to more *guided search paths* with less open-ended experimentation. This kind of directed and strategic guidance may be more common for infrastructural systems (which offer less scope for open-ended tinkering), especially when these involve relatively closed networks of powerful actors. Such closed, technocratic networks have previously been noted in a critical sense (e.g. Verbong et al., 2008), but our case shows that they can also produce remarkable successes.

A third criticism relates to the role of single projects. We question the generality of the earlier conclusion that single projects are not so important for niche development (Hoogma et al., 2002). While this conclusion may hold for discrete, mass-produced technologies (like cars or solar-cells), we suggest that it may not apply to urban infrastructural systems, which diffuse through space and time via actual construction projects. This deviates from the typical SNM-understanding, which assumes that projects are relevant for early experimentation (Kemp et al., 1998; Schot and Geels, 2008; Smith and Raven, 2012), but that innovations

subsequently diffuse through market adoption processes. For infra-systems, however, projects form the crucial diffusion vehicle *beyond* early formative phases. Although project sequences remain important (Geels and Raven, 2006), we specifically propose that *single* projects can have transformative effects on the emergence and diffusion of local infra-systems. Earlier scholars (Brown and Hendry, 2009; Hellsmark et al., 2016; Macey and Brown, 1990) distinguished two catalytic effects of demonstration projects: 1) *technically-oriented verification*, which establishes the technical or economic viability of a particular design (feature); this effect can increase niche momentum through strong contributions to learning processes (Figure 1), 2) *use-oriented exemplification*, which illustrates and confirms the appeal and attraction of a technology for wider audiences (e.g. users, policymakers); this effect can increase niche momentum by adjusting, confirming, or broadening visions and expectations (Figure 1). For local infra-systems, which are often capital-intensive, highly visible, and politically-loaded, we hypothesise that particularly successful single projects, which we call 'landmark projects', may markedly accelerate emergence or diffusion through these effects: they can decisively clarify particular design features and validate positive visions and discourses.

3 Methodology and data sources

To empirically explore the research topic (emergence and diffusion of local infrastructure systems) and our elaborations, we adopt a case study strategy, because this enables rich and real-world explanations that focus on the unfolding of developmental processes over time. As our case, we selected modern tramway diffusion in France (1971-2016), which involves light-rail infrastructure, complex configurations of technical components, considerable capital investments, and salient socio-political aspects (framings, advocacy, contestation, political motivations). Trams are localised systems, and so enable an investigation of sequences of local projects and the role of single 'landmark' projects. Tram systems intersect with the dominant auto-mobility regime and neighbouring regimes (slow modes, urban planning, railways).

We focus on France, because the country was amongst the pioneers of the light rail revolution – qualified as 'renaissance' (Foot, 2009; Kaufmann, 2013) and 'triumphant return' (Wolff, 2012) of global significance. French 'modern tramways' were initially developed as an alternative to urban (auto)mobility, but subsequently gained additional meanings as means for urban transformation. Figure 2 illustrates the diffusion of tram systems across various cities. Compared to other national settings, French tram diffusion has been strikingly successful, with trams spreading to nearly every city of more than 300,000 inhabitants, and in some instance to cities with less than 200,000 inhabitants (Figure 7). For larger cities (over 400,000 inhabitants) penetration reached 25%, 50% and 75 % by 1994, 2001, and 2010, respectively.

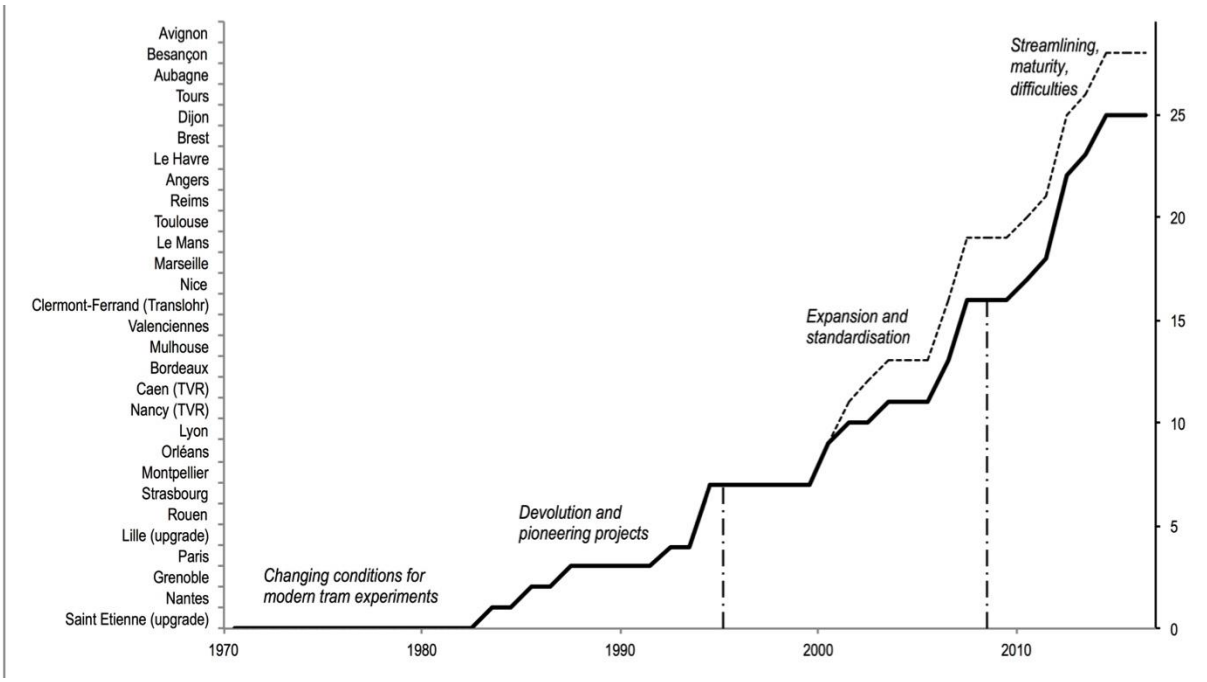

Figure 2: Modern tramway diffusion in French cities (solid line: tramways; dotted line: tramways and rubber-tyred tramways) (Data: Groneck and Schwandl (2014); Laisney (2011))

Data collection was guided by conceptual considerations, namely our interest in longitudinal diffusion trajectories, in project implementation, and in niche development activities. In a first step, we gathered background data from secondary sources. Specialised historiographies and grey literature were mobilised towards the elaboration of a multi-dimensional narrative account of the overall process (technological change and design specifications, planning and policy, industrial organisation, user contexts, environmental considerations), focussing on the most salient developments in each dimension. This motivated a closer inspection of particularly significant events and issues (costs, politics, socio-cultural framing), for which we mobilised scientific and technical publications.

In a second step, we selectively mobilised primary and secondary sources to more systematically document: individual projects (using reports from transport authorities and industry); shifting priorities in urban planning and transport regimes (from relevant policy and industry documents); shifting priorities of tram advocates (from industry association minutes and specialised tram journals); quantitative diffusion trends (using city-level data from public transport operators, relevant policy authorities, and transport atlases).
In a third step, we developed a longitudinal analysis (1971-2016), which spans the whole process from pre-development (including enabling political changes), to emergence, development and diffusion. We divided the process into several periods (Figure 2), which were chosen with particular attention to adoption trends, significant changes in the wider context (enabling conditions, strategic priorities), and qualitative shifts in the framing of local projects. Our analysis used a process tracing approach which is useful for investigating complex, multi-layered temporal phenomena (Langley et al., 2013). George and Bennett (2004) distinguish different kinds of process tracing such as detailed narrative, use of hypotheses, analytic explanation, and more general explanation. We aim for analytic explanation that converts a historical narrative of a specific case into an analytical explanation by identifying an overall pattern couched in explicit theoretical forms. This is not an easy procedure because of the richness and multi-dimensionality of our collected data. As Langley (1999:694) notes: "This is where the central challenge lies: moving from a shapeless data spaghetti toward some kind of theoretical understanding that does not betray the richness, dynamism, and complexity of the data". We address this challenge by explicitly organising

our analysis in terms of conceptual MLP and SNM categories, which address interlinked developments at different levels of granularity:

- Contextual developments in the wider landscape and established regimes (including auto-mobility, railways, public transport, urban planning)
- Field-level niche developments, which we analyse in terms of: a) visions and expectations, b) knowledge and learning, c) actors and social networks.
- Implementation of local projects, which can have site-specific twists and turns.

4 Longitudinal case study

From the mid-1970s, France experimented with modern tramways, which constituted a new trajectory, including substantial technical innovation, novel framings (around modern, environmental, and place-making values), governance and financial innovations. This early experimentation phase around a few projects led by pioneering cities was followed by widespread diffusion (Figure 2), which by the late 1990s started reducing urban car traffic.

4.1 1971-1983: Early landscape and regime changes as backdrop for modern tram experiments

4.1.1 Contextual developments

Auto-mobility and public transport regimes. During the 1950s and 1960s, French transport policy revolved around the expansion of private motorised mobility (Lannoy, 1999), with investments pursuing the objectives of '*tout automobile*' (full auto-mobility) (Gallez, 2010). Full auto-mobility largely conflicted with the remaining tramways, which were effectively dismantled (Passalacqua, 2011) or replaced by buses and by metro systems.

In the 1970s, this 'love of the car' encountered some political and intellectual opposition, as it exacerbated social inequalities (Boltanski, 1975). Oil crises (1973, 1979) highlighted issues of resource dependence, and opened up new discourses about the search for leaner alternatives. Campaigns for road safety, highlighting the shocking death toll on French roads, generated a desire to 'tame' the automobile. Increasing urban congestion led people to question the link between automobiles and freedom, creating opportunities for a reflection on what kind of car was desirable, how urban transport should be planned, and how alternatives could be supported.

Meanwhile, an ambitious high-speed rail development programme sought to develop connections between large urban centres. With research initiated in the mid-1960s, the subsequent deployment of the TGV (Train à Grande Vitesse) symbolised a decidedly French school of technological achievement, supported by a form of 'high-tech Colbertism' (Cohen, 1992), i.e. strong state involvement in strategic innovation and procurement through large projects.

Urban transport and planning regime. Nascent tensions around automobility and the continued decline of public transport led to a sense of crisis justifying coordinated interventions from the 1960s onwards (Kada, 2012), involving Government, local authorities and transport operators, around issues of social justice (equitable access to the city), early environmental claims (nuisance-free urban environment) and economic attractiveness (Gallez, 2010). The oil crisis (1973) exacerbated these tensions, accelerating the search for alternatives. The 6th Plan for economic and social development (1971-75) specified a way forward: "In terms of *traffic and urban transport* […] new investments will primarily concern heavy infrastructures (rapid lanes and segregated public transport) [in larger cities…] and experimentation with new public transport systems in a number of provincial cities" (Commissariat général du Plan, 1971:48, *original emphasis*, own translation).

New rules were developed to support more effective urban public transport planning. The Versement Transport (VT), introduced in 1971, provided an innovative financing mechanism

for large public transport schemes (raising employment tax locally to cover capital expenditures). First introduced in Paris, it was gradually extended to smaller cities (Figure 3). Originally intended as support for metro-like schemes, it generated a crucial funding stream for large projects (Laisney 2011). Strategic urban land-use planning approaches introduced in the late 1960s started to reflect new concerns around restricting car use and improving accessibility (Gallez, 2010).

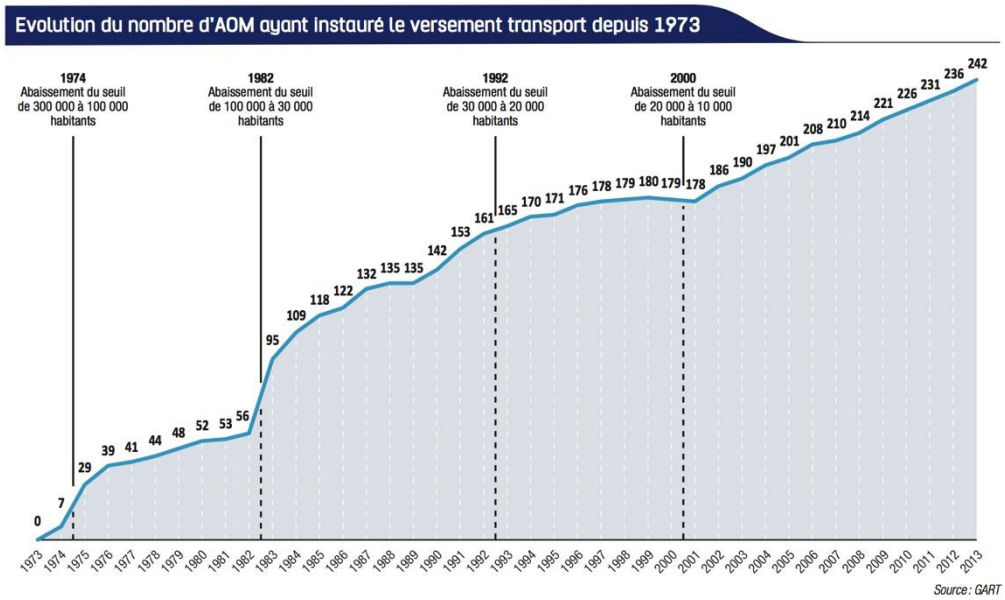

Figure 3: Evolution of French municipalities collecting local transport tax (1973-2013) (GART, 2015)

4.1.2 Niche-level developments

Visions and expectations. The search for public transport alternatives was approached as a technical challenge calling for ground-breaking solutions, inspired by the TGV model for long-distance travel. This justified experimentation, and a particular interest in spectacular projects such as the (failed) ARAMIS experiment to develop a personal rapid transit system (Latour, 1996), the (more successful) Véhicule Automatique Léger (VAL) – an integrated rapid transit system –, and work on guided buses (Foot, 2009) – all of which initially co-existed with trams[3] (Laisney, 2011).

Difficulties with these options and resource constraints in a post-oil crisis context (Vaudois, 2016) made the prospects of modern tramways increasingly attractive. A working group was formed around Marcel Cavaillé (Transport State Secretary from 1974) to develop a strategic vision and set of experiments. The Cavaillé circulaire (1975) called on eight cities to develop segregated public transport projects, providing experimental test-grounds. Although not directly leading to successful projects, it marks the "birth certificate of the modern tram" (Laisney, 2011:21). In parallel, the Cavaillé competition sought a technical offer to establish "the characteristics of a guided, electrically-powered means of surface passenger transport that could operate both on streets and in segregated lanes" (Demongeot, 2011, own translation).

Together, these initiatives were ambitious state-led impulses that aimed to create demand for and supply of trams, while also providing a strong symbolic push (Foot 2009). The national union for public transport insisted on the need for visible technological projects that

[3] Light metros are more costly and less flexible than trams, as they operate on segregated tracks (often over- and underground). VALs are a particular kind of light metro that is driverless and hence technologically more sophisticated.

could project a modern image (Vaudois, 2016) and generate export potential (Demongeot, 2011): "[a] light rail system must impress the public that its qualities are largely the same as those of metropolitan railways, and that it is modern, safe and punctual" (UITP, 1977:4).

Knowledge and learning. Light rail development drew from considerable expertise and research capabilities in the nationalised French rail industry, including train and signalling designs, component manufacturing, system integration, and operations (Davies et al., 2007). Nonetheless, a number of distinctive challenges justified continued expertise development, including power supply (catenary, third rail), crossing and co-existence with regular traffic, automatic safety systems, multiple platform heights (UITP, 1977:2).

Actors and networks. On the supply side, early experiments rested largely on existing industrial networks related to nationalised rail interests, with strong links to governmental decision-makers, in what can be seen as a powerful techno-political alliance. A close partnership between SNCF and GEC Alsthom ensured the concentration of design and engineering capacity (Cohen and Kamga, 2013), particularly from 1981: "the industrial strategy underlying the support accorded to Alsthom became more explicit. More than seeking a national champion, it [was] about promoting a nationalised group concentrating French rail know-how, domestically and abroad" (Demongeot 2011:205, own translation)

On the demand side, trams constituted a radical proposition that went against decades of pro-car urban planning. A major difficulty was the need to break with political inertia and resistance: mayors and civil servants having overseen the dismantling of tramway systems could not be seen to reintroduce it (Laisney, 2011). Tram development therefore largely rested upon radical proposals by political outsiders and new entrants willing to become associated with the emerging niche, notably the political novice Marcel Cavaillé and newly-elected Socialist mayors, e.g. in Nantes, Strasbourg. These mayors marked a rupture with dominant post-war Conservatism, and were entrusted with newly devolved powers.

Early on, networks formed to support the development of dedicated knowledge and advocacy, notably within industry bodies dealing with public transport. From 1978, the international union for public transport (UITP) set up a working group on 'light rail' to represent the industry's interests, which became instrumental in shaping the direction of innovation, the accumulation of knowledge, and standardisation of modern tramways, along with other advocates for modern public transport alternatives.

4.1.3 Local project implementation

This period saw the beginning of local interest in exploring various alternatives (i.e. VAL/light metro and modern tramways), with most larger metropolitan areas (Bordeaux, Nice, Strasbourg, Toulouse, Rouen) considering the heavier and costlier VAL option (Demongeot, 2011). In the late 1970s, detailed formal studies explored the possibility of modern tramways in Grenoble, Nantes and Strasbourg (Demongeot, 2007), though early projects encountered "political difficulties" (UITP, 1983). Nantes pioneered the first modern tramway in France (1985), following an election pledge of incoming Socialist mayor elected in 1977: "the tram was at that time an instrument of a postmodern revolution for the new mayor (Laisney, 2011:21). Further plans were underway in Grenoble, Marseille and Toulouse – although the latter eventually opted for a VAL (UITP, 1980).

4.2 1983-1995: Devolution and pioneering projects

4.2.1 Contextual developments

Urban transport and planning regime. Mitterrand's 1981 election signalled stronger strategic state intervention and major changes in urban mobility planning. The 1982 Defferre laws mandated substantial devolution of public transport competences and resources. In 1982, the LOTI law (on domestic transport guidance) established transport as a citizens' right, calling for 'reasonable' access provisions, establishing devolved public transport

responsibilities for various territorial levels, encouraging the development of strategic urban mobility plans (Plans de Déplacements Urbains – PDUs) by local authorities, and mandating socio-economic assessments of transport projects. In the same year, the Versement Transport (VT) was extended to cities of 100,000 inhabitants (Figure 3).

Environment and sustainability regime. Internationally, this period saw greater emphasis on environmental issues, e.g. UN Brundtland Report on Sustainable Development (1987), first IPCC report on climate change (1990), UN Rio Declaration on Environment and Development (1992), which stimulated interest in more sustainable alternatives. In the 1990s, the European Commission supported the development of international networks for environmental urban planning (Chabanet et al., 2015), and considered the radical proposition of car-free cities (Ciuffini et al., 1991). In France, a number of cities experimented with urban environmental charters, but these were criticised as top-down and largely symbolic efforts.

Auto-mobility regime. Auto-mobility had come under significant pressure during the 1970s and 1980s. Figure 4 shows the evolution of the relative share of car trips against alternatives in cities, displaying a slowing-down of auto-mobility growth in the late 1980s a reduction from the late 1990s. Figure 5 shows similar trends in a variety of cities, with particularly striking results in Grenoble and Strasbourg (early tram adopter cities with particularly extensive coverage).

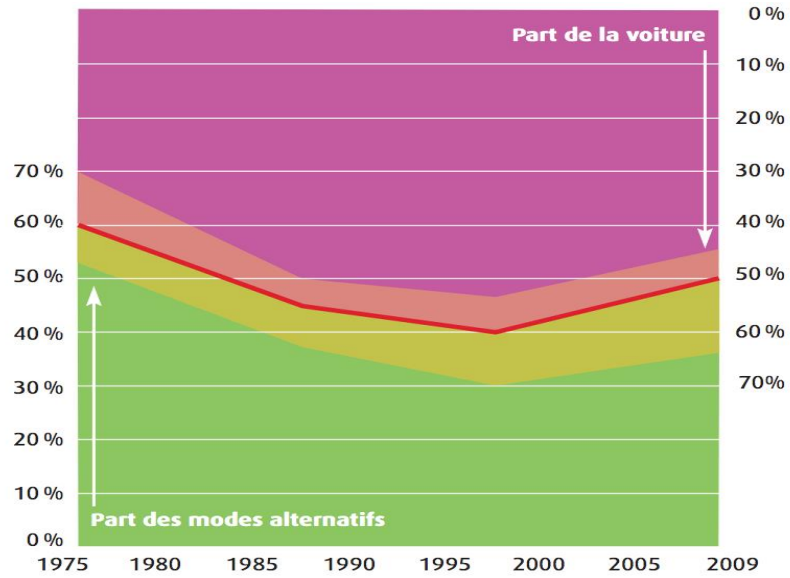

Figure 4: Evolution of modal split in France in cities >250000 inhabitants (CERTU, 2010)

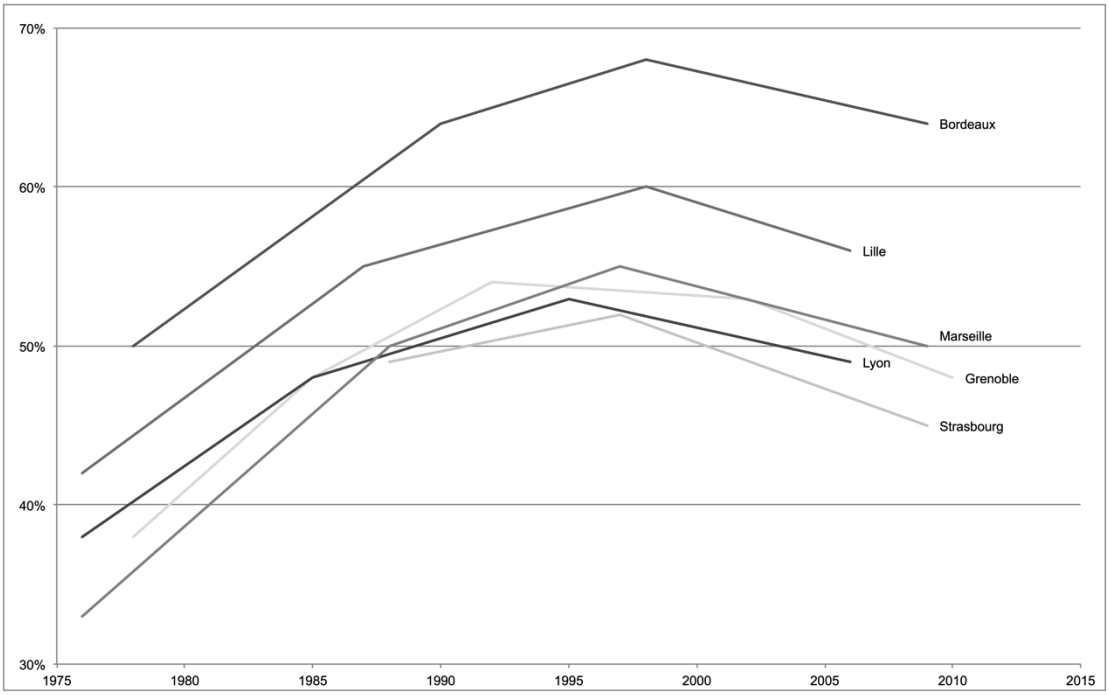

Figure 5: Evolution of car use (percentage of journeys) in selected French cities (Data: CERTU (2013b))

4.2.2 Niche-level developments

Visions and expectations. Implementation problems with light metros shifted attention towards tramways as attractive solution. This top-down vision was supported by generous funding and oriented towards modernist and 'patriotic' ideals of high-tech industrial achievement. A 'Technical Committee for the Standard French Tram', bringing together various actors in the field, was created under Government impulse in 1982. The committee took on the role of intermediary organisation with the objective of "ensuring that the various requests of local authorities would be confronted to industrial constraints and led to the elaboration of a standardised French rolling stock viable for export" (Demongeot 2011:207, own translation). But the tram also needed to come into contact with and convince end users on the ground, become appropriated and desirable (Demongeot, 2011; Olesen and Lassen, 2016). High quality service and design were commonly put forward as means of seduction.

Knowledge and learning. The top-down 'push' for technology development, resting largely on established actors, led to significant results: "France has a long-standing reputation in many fields for technical innovation along with a tradition of supporting the products of native companies – both areas apparent with its tram fleets. However, when the first modern systems were emerging, France had little in the way of light-rail products (…) With this in mind, the response of Alstom (…) in such a short time to the burgeoning domestic market has been as noteworthy as the proliferation of light rail systems."[4]

Developing local implementation knowledge proved more challenging. Although trams benefitted from substantial government support – up to 40% of total investment in the 1970s, and averaging 15% in the late 1980s (ACUF, 2007) – they faced latent local opposition (Lois González et al., 2013) to car-restrictive policy interventions, e.g. parking restrictions, suppression of roads, priorities at crossings (Debizet, 2011). Local policy communities and advocacy groups were crucial to retain the practical experience gained in successful projects (Demongeot, 2007). Dedicated bodies and experts allowed the accumulation and circulation of this knowledge between local transport authorities and technical bodies (Hamman, 2015).

[4] http://www.railway-technology.com/features/feature1096/, accessed 12 January 2017

Technical bodies, research centres and specialised Government-affiliated technical services, played an important technical and engineering advisory role on behalf of the State and local authorities, overseeing large projects and feasibility studies. Intermediary actors and specialised public transport organisations were created to develop the capacity to circulate and accumulate knowledge and expertise: "In connection with the administrative machinery of the local authorities […] an increasing number of specialized structures in the public transport field were created […]. These service providers and intermediaries establish[ed] renewed and widened diffusion networks, which attest to the reality of the interactions with the economic circles" (Hamman, 2015:202). Public transport unions were particularly concerned with technical standards and the development of attractive features.

Actors and networks. Dedicated services and expertise around urban transport, crucial to the alignment of the tram with urban planning, became increasingly formalised. With the LOTI law (1982), urban public transport became an explicit responsibility of local authorities, coordinated by dedicated inter-communal syndicates. Their federation ensured the pooling of expertise, knowledge exchange and interest representation at national level, and greater capacity for lobbying for more favourable regulations and frameworks.

New entrants emerged alongside powerful established rail industry actors. Egis Rail and SEMALY (two organisations that arose from mergers of companies involved in the development of Marseille and Lyon metros) played a crucial role in early tram projects and subsequently became world leaders in rail and urban transport engineering (Laisney, 2011).

4.2.3 Local project implementation

The first French (and European) modern tram scheme was delivered in Nantes (1985). It was a major landmark for the industry, establishing the first generation of 'Tramway Français Standard' (TFS) developed by Alsthom (Taplin, 2010). The tram was deliberately made highly visible (no underground sections). In terms of mobility planning, it was conceived as a new backbone of public transport, particularly through the reorganisation of buses as feeders/extensions to tram lines.

Grenoble's tramway system, opened in 1987, pushed further innovations. Anticipating potential opposition during the construction phase (a lesson from Nantes' implementation), the project was approved by referendum and included modalities for the compensation of local businesses. Local controversies informed innovation activities such as the development of low-floor carriages for increased accessibility for disabled users. The Grenoble network was also particularly attentive to seamless integration in the city (including the full pedestrianisation of a segment crossing the urban centre) and an explicit framing as "mobile public space" (Laisney, 2011:23).

The Strasbourg project was more of a bumpy ride. Developed in 1985, it was revoked in 1988 in favour of an underground VAL. In 1989, incoming Socialist mayor Catherine Trautmann developed a radical new tram proposal, staged as a struggle with auto-mobility: "The re-conquest of the space that had been confiscated by auto-mobility, with a stated ambition to reduce its use, became a civilisation battle, leading to the most spectacular metamorphosis of urban space in any French city" (Laisney, 2011:23, own translation). Particular attention was paid to the definition of public space, technical and design features (low-floor, bay windows, 'hyperfuturist design' (Guillon, 2013)), and the development of park-and-ride facilities – made possible because of prior funding allocation for a much costlier VAL. The inauguration (1994) marked a qualitative threshold for French trams (Laisney, 2011), embodying its 'renaissance' (Kaminagai, 2014).

Less successful schemes included Rouen, for which the construction of underground sections led to cost overruns. The first Paris project (T1) encountered problems limiting its transformative impact.

4.3 1995-2008: Expansion and standardisation

4.3.1 Contextual developments

Environment and sustainability regime. Air pollution and sustainable development became more central in public and policy debates. The European vision for sustainable cities (EC 1996) and a widespread movement around the Aalborg charter (Chabanet et al., 2015) led to the pursuit of soft mobility, Local Agenda 21 and Climate Plans. These shifts also informed French regulatory changes.

Urban transport and planning regime. The 1996 LAURE law on energy and clean air was a significant milestone, under which strategic urban mobility plans (PDUs) introduced in 1982 became mandatory. This led to the local institutionalisation of energy and air pollution measures and car reduction objectives (Demongeot, 2011). The 2000 law on 'solidarity and urban renewal' introduced mandatory social housing objectives, supported more coordinated planning between municipalities, and mandated the search for car restriction options. The gradual strengthening of car reduction objectives in urban transport planning was instrumental for the multiplication of tram projects: "This is a political objective and [light rail] development has become one of the means of achieving it" (Hylén and Pharoah, 2002:9). The Barnier Law (1995) institutionalised the rules for public debate and consultation around new transport projects, mandating a two-stage public consultation procedure.

Central Government funding for public transport projects became more codified, via governance guidance circulars (1994, 2001), with largest shares provided by the Versement Transport (increased contribution) and local authority budgets. From December 2003, Government funding for light rail was substantially decreased on budgetary grounds (ACUF, 2007). These cutbacks delayed projects and increased reliance on loans (Faivre d'Acier, 2010), cross-financing, and European loans (ACUF, 2007) (Table 1).

Table 1: European Investment Bank involvement with French tramways (2006-2012) (Source: EIB)

Date	Press release
15/06/2006	France: EIB lends EUR 120 million for construction of Le Mans tramway
29/09/2006	France: EIB lends eur 150 million for Marseille tramway
01/05/2007	France: EIB lends EUR 150 million for Nice Tramway
26/09/2008	France: EIB lends EUR 175 million for CLEO, the tram system of Orléans
04/07/2011	France: EIB lends EUR 250m to finance line 3 of the Montpellier tramway
07/11/2011	France: EIB lends EUR 300 million to finance Île-de-France tramway
16/03/2012	Île-de-France Tramway: EUR 200 million for sustainable, quality infrastructure

4.3.2 Niche-level developments

Visions and expectations. New framings emerged in this period, aligned with a strategy to extend the tram's attractiveness to an increasing number of cities. The tram became a tool of urban marketing, promoting 'emerging' urban areas (often for business and touristic attractiveness) and projecting city-image globally. Developers emphasised visible landmarks, quality, and modern aesthetic – a vision criticised by some as distracting from the more structuring potential of public transport (e.g. accessibility, social inclusion) (Frenay, 2005). The importance of tailored design became apparent with development of Alstom's Citadis, enabling increasing modularity and custom features, and opportunities for bespoke rolling stock design (Guillon, 2013). Mayors took up this new potential, commissioning established designers and artists at the service of city branding and marketing (Kaminagai, 2014): "For elected officials, the tramway [became] a tool for urban requalification and an ideal instrument of urban marketing" (Lois González et al. 2013:633).

Figure 6: Bordeaux and Nice tramways (Images: Mailhot, M.-M.; Zil)

Knowledge and learning. Along with more specific financing rules and mechanisms, the 1994 and 2001 'guidance circulars' provided more direction (specific evaluation criteria, including social and security objectives) and further institutionalisation of technical expertise. CERTU[5] (Assessment centre on networks, transport, and public works) and its affiliated regional centres became more active, delivering technical manuals, evaluation guidelines, centralisation of comparative learning, user observations and surveys, etc. These governmental technical services developed urban travel observatories, technical studies, technical notes about particular options, further supporting learning from and between localities. Since 2001, a dedicated technical advisory body (STRMTG) for guided transport[6] included technical control and evaluation functions, and oversaw safety and standardisation issues through its 'tramway division'.

This period also saw growing involvement of consultancy and engineering companies, which supported the international circulation of experts (Debizet 2004) and allowed the identification, dissemination and replication of exemplar 'success stories'. The stabilisation of modern tramways and their diffusion was supported by increasing reproducibility (Hamman, 2011a:14), enabled by standardised design features (Bérard, 2009) and enacted by the circulation of technical teams implementing the projects. Indeed:

> "the fact that the tram in Montpellier was inspired by the example of Strasbourg illustrates [this reproducibility] (in the same way as the tram network in Strasbourg takes us back to the 'model' of Grenoble). It was the same technical team that implemented the project (the engineers went from Strasbourg to Montpellier after a political change of the municipality in Strasbourg) and the chosen tramway trains had already been successfully tested elsewhere (the Citadis of the Alstom Company). The reference to a 'model' and then its local adaptation […] is a guarantee of the practicability of the scheme." (Hamman 2015:198).

Standardisation was also pursued at the European level.

Actors and networks. Alstom continued to improve its offer and associated export potential (e.g. from TFS to the new Citadis). Multinational operators of local transport services, dominated by French companies (Keolis, Connex/Veolia Transport, RATP), also became more influential. Central Government started exerting a lighter top-down influence, as evidenced by decreased funding. The devolution of responsibilities to local echelons led to the strengthening of private forms of expertise (engineering consultants) (Debizet, 2004).

On the demand side, the tram frenzy diffused across the political spectrum (while car restrictive measures had until then exclusively emanated from the Left), as a number of Conservative mayors of larger cities opted for the tram (Bordeaux, Marseille and Nice) (Laisney, 2011), signalling its mainstreaming and establishment as a legitimate urban

[5] CERTU was created in 1994, merging existing urban planning and urban transport technical competences.

[6] http://www.strmtg.developpement-durable.gouv.fr/

mobility intervention. The retention of power, resources, and expertise at local implementation levels (Demongeot, 2011) is particularly striking compared to other countries.

4.3.3 Local project implementation

This was a period of significant tram diffusion (Figure 2), notably in 'large cities' and increasingly also in 'smaller cities' (Figure 7). The success of the Strasbourg tram led to a flurry of new tram network proposals (Laisney, 2011).

- The Lyon project was noteworthy because of the unprecedented speed of construction (two simultaneous lines delivered in 2001).
- Montpellier (2000) put particular emphasis on aesthetics, commissioning famous artists and architects, but also attracted local criticism related to noise.
- The Orléans project was more controversial, due to political struggles about the most suitable option (tram or trolleybus).
- The large and costly Paris project resonated with Strasbourg's "civilisation project", with substantial recovery of public space and ground gained over the car (although the tram remained complementary to the metro). It attracted significant (car user) opposition, because construction caused traffic disruptions.
- The Bordeaux project, presenting similarities with Strasbourg (tram as transport backbone), spectacularly opened three lines simultaneously (in 2003). For conservation motives, the APS innovation (ground-level power supply) was developed to reduce the visual impact of overhead lines.
- Marseille inaugurated its first two lines in 2007, as a means to extend its metro network (following Lyon's example). In a similar way to Bordeaux (and Strasbourg before), Marseille's tram, effectively 'locking' the urban core, allowed ground to be regained over the car.
- Nice inaugurated its first line in 2007, transforming the urban centre, pedestrianising historic piazzas and commissioning permanent art installations (Vaudois, 2016). It strikingly demonstrated cumulative learning from earlier projects, effectively closing the loop of the tramway's renewal, and actively mobilising the skills and experience acquired (Laisney, 2011).
- For smaller former industrial cities, the tram was a sign of renewal and regeneration, re-qualifying urban centres, and connecting major social housing sites (Laisney, 2011) in Saint-Étienne (2006), Mulhouse (2006), Clermont-Ferrand (2006), Valenciennes (2006), and Le Mans (2007).

4.4 2008-2016: Maturity, streamlining and difficulties

4.4.1 Contextual developments

Environment and sustainability regime. Environmental objectives gained further centrality, notably through the creation of a Ministry for Ecology also overseeing urban planning and transport. The 'Grenelle de l'Environnement', established in 2007 as a roundtable about environmental and sustainability governance, led to the specification of long-term sustainable development and public transport objectives. It established national tenders for tramways along with an objective to deliver 1800km of segregated public transport by 2020 (Grenelle II law (2010)).

Urban transport and planning regime. After a relatively 'dry' period since 2004, Government re-introduced central funding for public transport under a new mechanism from 2008 with a raised overall budget, on the basis of punctual calls for tenders (2008, 2010, 2013). While this increased the overall budget, this was spread more thinly over a greater number of projects, leading to a preference for lower-cost options from 2010, relatively

weakening the tram proposition.[7] This period also saw a substantial expansion of high-level bus services (namely 2012-2015). This direct competition on cost terms led to the abandonment of a number of tram projects. Further territorial planning reforms (e.g. via the creation in 2010 of 'Metropolitan poles') intended to link urban areas in adjoining communes were expected to favour public transport extensions beyond large and medium urban areas.

4.4.2 Niche-level developments

Visions and expectations. After decades of pioneering schemes, the framing of motivations for tram projects in France became highly convergent: "Urban sustainable development and environmental preservation, renewal or requalification of urban space (privileging the opening up of sensitive urban areas), mature technology, "tramway effect" on job creation are the arguments most commonly put forward to justify tramway projects" (Pissaloux & Ducol 2016:183, own translation).

However, French tramway schemes, owing to their relative short length and number of lines, also performed less well as a tool of wider territorial cohesion (Pissaloux and Ducol, 2016). This issue justified shifting the focus towards greater territorial coherence (Lois González et al. 2013) and cost-effectiveness. Indeed, commentators have suggested that the two decades of tram 'fad' in France, seen as desirable by mayors and local authorities, often neglected economic considerations. The president of the Union of Public Transport, for instance, commented that: "Elected mayors, constructors and operators treated themselves by building schemes of an extreme quality, often at a high cost".[8] Opposition on cost grounds became more salient (Pissaloux and Ducol, 2016), and the tram became less easy to justify, as evidenced by multiple abandoned projects.

Knowledge and learning. The standardisation of technical and design features continued. Indeed, the design specification of French trams "are now used in export, because the building consultants, the transport operators and the designers intervene in response to a growing number of cities in the world, on the base of the references created in the French cities" (Kaminagai 2014:62).

Domestically, established knowledge networks increasingly focussed on optimisation issues, in order to cut costs, re-invigorate the eroded political proposition, and address problems in existing networks. Trams have to some extent become victims of their own success due to increasing congestion issues, which provided a motivation to optimise network operations (CERTU, 2012).

Actors and networks. On the supply side, French tram manufacturers (e.g. Alstom), operators (e.g. Keolis, Transdev, RATP) and engineering firms (E.g. Vinci, Bouygues) increasingly turned to export markets. Domestically, Alstom's position became less monopolistic as Marseille purchased Bombardier's Flexity Outlook rolling stock, Paris (T4) and Mulhouse opted for Siemens' Avento, Besançon, and Nantes for CAF's Urbos.

On the demand side, this challenging period (budget restrictions, especially in smaller cities) led to a push for cost-effective innovations, as well as a number of abandoned schemes. Nonetheless, the diffusion of French tramways over the last decades has led to the build-up of substantial operational teams, increasingly focussing on continuous network extension, maintenance and improved viability.

[7] http://www.lemonde.fr/mobilite/article/2012/11/23/le-tram-en-bout-de-course_1794319_1653095.html

[8] Marc Janaillac, president of the UTP, interviewed for *Les Echos*, https://www.lesechos.fr/03/11/2014/LesEchos/21806-060-ECH_jean-marc-janaillac-----la-sncm-est-le-symbole-des-blocages-que-rencontre-la-france-pour-se-reformer--.htm (own translation)

4.4.3 Local project implementation

Eight new networks benefited from recent innovations, which sought to provide links to socially excluded neighbourhoods and consider sustainability objectives. Toulouse (2010) followed Lyon's example (itself followed by Marseille), deploying tramways to extend its existing heavier VAL network. Brest (2012), Reims (2011) and Tours (2012) delivered projects that had been in gestation for decades. Reims involved an innovative financial model. Projects were also delivered in smaller cities (Angers, Dijon, Le Havre, Aubagne, Besançon), at relatively low costs (particularly Aubagne and Besançon).

Figure 7 illustrates how size thresholds were crossed over time: initially, trams were developed for large non-millionaire cities (300-600,000 inhabitants), spreading to both smaller (>300,000 inhabitants) and larger cities (>800,000 inhabitants) during 2000-2010, and later venturing below 200,000 inhabitants, which had until then been seen as "the threshold below which the tram was not viable" (Hasiak & Richer 2012:16).

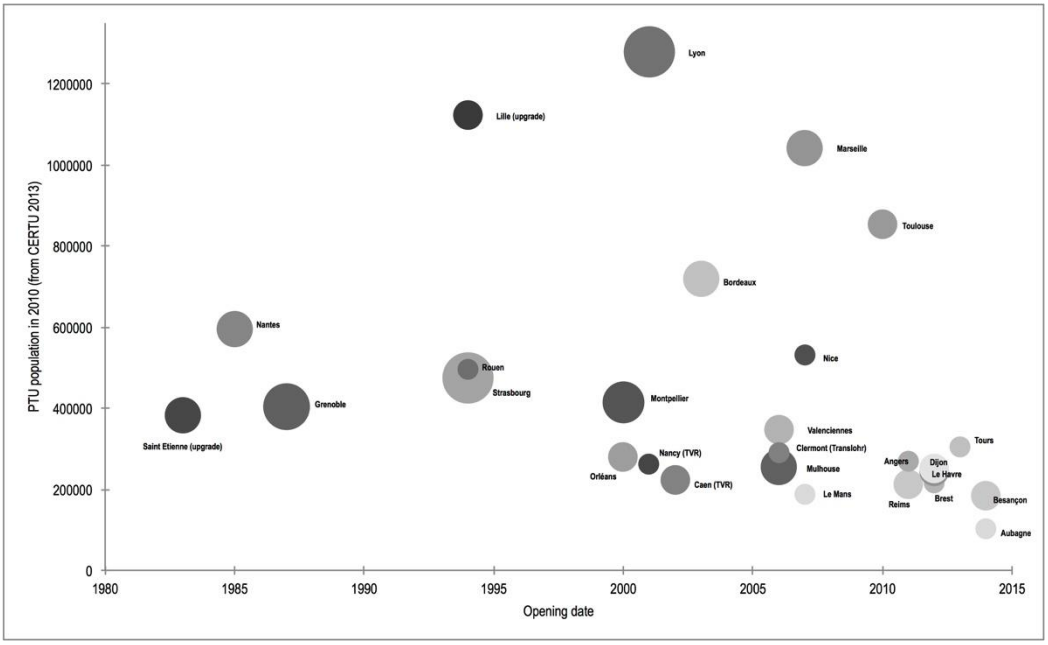

Figure 7: Adoption of modern tramways by French cities (excluding Paris) according to urban area population (2010), circle size represents current number of lines (based on data from CERTU (2013))

Despite this continued diffusion, there were also signs of exhaustion as cost concerns led to the abandonment of local projects, notably around the 2014 local elections: "Although the number of cities with a tramway has doubled, the total length of tramway lines trebled, and patronage quadrupled from 2000 to 2010, the abandonment or downsizing of projects has become more frequent, notably concerning the cities of Amiens, Angers, Avignon, Bordeaux and Caen" (Cours des Comptes 2015:276, own translation).

Construction started on the Avignon tramway, due to be opened in 2019, following 'ups and downs' since 2010.[9] Construction started in May 2017 to convert Caen's TVR into a conventional tram.[10] A number of existing networks were significantly extended (Grenoble, Strasbourg, Montpellier, Lyon, Bordeaux, Orléans, Marseille, Paris, Nantes), marking a move towards consolidation.

[9] *Tramways and Urban Transit*, July 2017, 249.

[10] *Tramways and Urban Transit*, July 2017, 270.

5 Discussion

French tram diffusion followed a systematic niche development process, which shifted from initial pioneering projects to more structured development and wider diffusion. Section 5.1 provides an analytical summary of the niche development trajectory, structured by established SNM-concepts. Section 5.2 then draws three conceptual specificities from our case, which deviate from the archetypical understandings.

5.1 Explaining the emergence and diffusion of modern tramways

Table 2 provides an analytical summary of the case in terms of core niche development processes (visions, knowledge, actors) in each period.

Table 2: Core niche processes for modern tramways in France

	1971-1983	1983-1995	1995-2008	2008-2017
Visions & expectations	National visioning & industrial strategy, top-down search push for segregated urban public transport, in collaboration with rail industry; search for 'candidate' cities	National visioning (dedication to high quality standards) and emergent local 'models' & new features (e.g. urban transformation, opportunity for radical projects)	Multiplication and broadening of framings; emergence of new paths (e.g. lower costs, smaller cities, tram-train, rubber-tyred)	Under increasing pressure (e.g funding), focus on addressing criticisms (e.g. cost optimisation, territorial coherence), streamlining, and improving up export potential
Knowledge & learning	Existing supply/expertise networks (largely incumbents)	Circulation of knowledge and expertise	Success with realising vision; Generic and mobile knowledge, increasing standardisation at national and European levels	High standardization of base features, further exploration of streamlining and cost-reduction
Actors and networks	Supply-side incumbents (rail and state); New entrants (mayors) discover emerging space	Situated local networks (w/ nation-wide coordinated technical networks); Users discover benefits; New roles (consultants and operators)	Far-reaching networks (trans-local, inter-local, global); Technical administration, consultants, and operators	Far-reaching networks; increased foreign competition (supply-side)

Developments over time and the interplay between niche- and project-level dynamics generated the following patterns:

- *Knowledge and expertise* accumulated and stabilised over time. Early tram developments largely built on existing knowledge, skills and capabilities retained within the existing rail industry, which was adapted to tram-specific challenges. Local solutions to such challenges led to gradual improvements of design features, which were further developed in subsequent projects. Circulation and aggregation enabled knowledge accumulation, which was oriented towards standardisation. The multiplication of tram projects was accompanied by efforts to streamline design standards and to systematically learn from successes and difficulties. The circulation of knowledge between implementation sites ensured learning from failures and retention of successful features, which culminated in a focussed and internationally recognisable 'French tram school' (Kaminagai, 2014). This design tradition was supported by the professionalisation and concentration of technical skills, which also became linked to urban sustainable development agendas (Desjardins et al., 2014). Problem-solving activities in later projects increasingly focused on specific technical, political and financial challenges associated with wider diffusion.
- Committed *actors and networks* proved essential, as diffusing tram systems were supported by a broadening alliance that included both established actors (national policymakers, rail industry, urban planning officials) and new entrants (cities/mayors, users). The Ministry of Transport provided a clear direction (through visions and R&D funding), while an established technical bureaucracy (at various territorial levels)

supported knowledge development and learning processes. Modern tramway projects were championed by determined local politicians (often as mayoral election pledges) who were enabled by major reforms that devolved powers and resources to local administrations. Local actors were initially enrolled around narratives of improved functional mobility, while national and industrial actors engaged around the promises of ground-breaking innovation and its export potential. Early projects demonstrated the feasibility and transformative value of 'modern trams', bolstering expectations of enthusiasts and supporters. The tram subsequently widened its appeal beyond these early enthusiasts and allies. It became appropriated by local politicians (as trams demonstrated their capacity to support electoral wins), by users (who largely embraced them, despite initial public objections), and by advocates of various societal issues. The emergence of specialised roles (local transport operators, regional experts, design studios) further densified the network of committed actors.

- Tram development and diffusion were strongly supported by a coherent *vision* for modern rail-based public transport alternatives, framed as a radical solution to reinvigorate urban public transport in the post-oil shock context. This vision sharpened over time and also broadened its appeal through *issue linkage*. Notably, early visions were politically-mandated and revolved around technological excellence, industrial policy and urban transport improvement. At the local level, we observe initial difficulties with the implementation of these visions, leading to political struggles and experimentation around technical specifications and framings, which were negotiated according to local conditions. These early projects influenced the top-down visions and framings, gradually turning the interpretations of trams into a means to modernise cities and reclaim them from the car, as well as an outward-looking city marketing tool. Later visions thus moved beyond transport-specific considerations and became framed around wider issues such as urban transformation, quality of life, and environmental problems. Visions thus took on new meanings that aligned with emerging norms and values (e.g. access, sustainability, liveability, urban renewal), which broadened the attractiveness of trams to local authorities, mayors and other actors. So, the multiplicity of non-exclusive framings that became linked to the tram widened its appeal and helped to build a broad discourse coalition. The 'French tram school' became a blueprint for major projects that were "placed above political controversies, by incarnating the general interest of the city" (Hamman 2015:198), imposing a particularly effective transformative instrument that could hardly be contested. So, the locally transformative effect of trams enrolled new actors for its advocacy and legitimation. The tram became 'irresistible' for any medium and large city.

5.2 Case-specific conceptual implications

The role of incumbent actors

Contrary to standard assumptions in SNM, the emergence and diffusion of modern trams in France was strongly influenced by incumbent actors who contributed to initiating, accelerating, and directing niche development. The tram niche was initiated by a small group of actors comprising the Ministry of transport (actively seeking urban public transport alternatives), the leading railway industry actor Alstom (interested in a potential new market opportunity mobilising existing capabilities and competences), and established public transport interests (advocating or facilitating the development of alternatives). These actors were incumbents, in the sense that they constituted established and powerful actors relevant to (urban) mobility, but were not directly linked to the dominant regime (*auto*mobility). Instead, they came *from neighbouring regimes* (e.g. railways, public transport, urban planning, transport policy, public sector technical expertise) and had varied interests in supporting alternative system innovation and challenging the dominant regime. The early

involvement of incumbent actors (mostly on the supply side) accelerated and focussed niche development, due to significant available expertise, a strategic political mandate, and the ability to maintain a relatively focussed and coherent direction of search. On the demand side, we also note the crucial involvement of high-level local politicians (mayors) that allowed the multiplication of full-scale projects and the rapid normalisation of 'modern tramways' as techno-political object. So, early buy-in and commitment from established actors has been a crucial factor contributing to successful diffusion.

Comparatively, new entrants did not show much interested or play an important role in niche initiation (indeed, the first call for cities to develop tram projects (in 1975) was left unanswered). They were important, however, to generate and activate demand (early adopters were largely new entrants championing radical transformative interventions), to further shape tramway framings (notably towards more radical kinds of interventions such as combining the tramway with major urban transformation plans or societal concerns), and later to support the development of specialised or streamlined features (e.g. consultancy services, design studios). The case thus involved alliances between new entrants and incumbents from neighbouring regimes, which is an interesting pattern that deviates from existing dichotomies.

The role of guided search paths

Initial niche formation was strongly influenced by *top-down visions*, particularly concerning technical aspects and design features. Strategic guidance of innovation activities emanated from a coherent and consistent R&D programme, initiated by the Ministry of Transport. This included specific criteria for technology development, a clear vision for industrial development (technological excellence, standard setting, international leadership), denoting a particularly 'hands-on' policy style. This *guided search path*, supported by substantial national and local funding streams, provided strong directionality from the start, limited design variation to a few alternatives, and led to an early focus on standardisation. The technological push was complemented by the stimulation of demand for ambitious urban public transport projects, namely through new planning priorities and procurement strategies. This strategic combination considerably streamlined the innovation process and reduced associated risks by allowing the recombinant exploitation of existing technical skills and capabilities of large industrial actors, the early accumulation and circulation of knowledge in dedicated public sector expert networks, and focussed learning and standardisation. As the tram niche acquired momentum and became 'irresistible' from the late 1990s, this hands-on approach was downscaled.

So, our case shows that niche development can be highly focussed from the start, rather than initially involving open-ended, exploratory experimentation and tinkering. We see this as an alternative niche development pattern (strategically guided). Strategic guidance has considerably accelerated innovation and diffusion in this case, enabled by strong state involvement in strategic innovation and procurement through large projects. During the later diffusion process, the vision broadened rather than becoming more specific, as SNM-scholars suggest (Schot and Geels, 2008). Trams became increasingly linked to multiple issues and purposes (e.g. as tools for urban remodelling).

The role of landmark projects

Our analytical periodisation identified different adoption phases: significant upswings in niche momentum from pioneering projects (1983-1995: 7 projects), niche expansion and standardisation (1995-2008: 12 projects), and mainstreaming and signs of maturity and difficulties (2008-present: 9 projects) (see Figure 2). Our case confirms the importance of the multiplication and sequencing of projects for sustaining niche momentum and generating positive feedback on core niche processes (see section 5.1).

In addition, we also find that certain projects played a more important role than others, acting as *landmarks* along niche development trajectories. In section 2.2, we suggested that landmark projects can accelerate developments in two ways:

1) *technically-oriented verification:* decisively demonstrating the technical or economic viability of a particular design (feature),
2) *use-oriented exemplification:* decisively demonstrating the societal appeal of new systems and user enthusiasm.

Our case provides evidence of single projects having both effects, as summarised in Table 3 (and described in more detail in section 4).

Table 3: Landmark French tramway projects

		Landmark function	
Project (delivered)	**Distinctive feature**	**Technically-oriented verification**	**Use-oriented exemplification**
Nantes (1985)	1st modern tram in France and Europe	Established feasibility and commercial viability of trams	Confirmed expectations of actors involved; emphasis on visibility and modern image
Grenoble (1987)	2nd modern tram in France	Established principle of pedestrianisation and seamless urban integration	Established innovative public consultation and compensations (improving social acceptance)
Strasbourg (1994)	Tram as transport backbone for wider urban transport system; very high budget	Integration of tram and urban transformation (e.g. pedestrianisation, multi-modality)	Established political viability of extensive car restrictions and political gains from trams
Bordeaux (2003)	Large project with strict historic conservation constraints (overhead cables undesirable)	Established feasibility of ground-level power supply	n/a
Nice (2007)	Synthesis of previous design features	Technological maturity (synthesis of cumulative learning and features)	n/a
Le Mans (2007)	Low-cost tram	Feasibility of low-cost tram	Pluralised tram vision (diversification)

These projects became landmarks because of the significance of the verification and exemplification that resulted, but also because their design implications were systematically replicated in later projects, supporting step-changes in the overall innovation and diffusion trajectory (by opening up, confirming, or closing down innovation paths). So, landmark projects had a crucial influence on the *speed* of niche development (accelerating subsequent diffusion) and on its *directionality* (focusing search paths).

While some of these landmark projects only emerged as such after the fact (e.g. Strasbourg establishing the political viability of more radical interventions combined with the tram), we also observe a more purposive focus on establishing landmarks: there was an early insistence that tram projects should be developed as highly visible interventions that could project a modern image of technological achievement. Accordingly, attention to staging was important: emphasis on visibility and spectacular arrival in the urban landscape reinforced the perceived effectiveness the tram as embodying the success of public intervention (Richer and Hasiak, 2012).

6 Conclusion

Focusing on the emergence and diffusion of radical innovations, this paper has confronted the archetypical understanding in the sustainability transitions literature, especially SNM, with an in-depth case study of French tram systems, which represents a particular technology class

(local infrastructure systems). We demonstrated the relevance of existing SNM-concepts for understanding the case (see section 5.1), but also identified three important deviations, namely about the role of incumbent actors from neighbouring regimes, guided search paths, and landmark projects. The wider implication of these deviations is that transition processes (in different countries, systems, technology classes) may be similar in terms of fundamental causal mechanisms, but different in terms of patterns, depending on how causal mechanisms temporally interact and what roles various actors play (which depends on context-specific coalitions, interpretations, strategies, opportunities).

Our finding with regard to the positive role of incumbent actors suggests that niche-regime interactions should be studied symmetrically. We therefore propose that scholars not only analyse niche-to-regime activities (which currently dominates the literature), but also regime-to-niche activities. The latter may include strategic reorientation of incumbent actors in the focal regime (Bergek et al., 2013; Berggren et al., 2015; Penna and Geels, 2015; Turnheim and Geels, 2013) or of incumbent actors in neighbouring regimes (as in our case). The latter may offer a way to mobilise counter-veiling power against locked-in 'focal' incumbents, not just in a political sense (Hess, 2013), but also in terms of capabilities and financial resources. Other examples of this pattern include ICT companies moving into renewable energy generation or Google moving into the automotive industry. These issues provide fertile ground for the study of sustainability transitions, which may uncover a greater variety in the patterns of niche development, including coalitions between new entrants and incumbents (from neighbouring regimes), as in our case.

Our finding with regard to specific visions and *guided search paths* offers a valuable counterpoint to the established SNM logic. One reason for SNM's emphasis on open-ended, evolutionary exploration in early phases is that there are many (historical and contemporary) examples of failures of strongly guided initiatives and system changes, either state-led (Scott, 1998) or coordinated by closed networks dominated by incumbents (Verbong et al., 2008). The suspicion of 'top-down' technocracy permeates the sociology of innovation and, more broadly, has been discussed for decades in political science debates about the pros and cons of planning versus incrementalism (Lindblom, 1959). While not resolving this fundamental debate, our case shows that strong guidance and early direction-setting *can* be effective in stimulating radical innovation. This may be particularly relevant for infrastructural systems (where open-ended tinkering is less feasible) and for addressing urgent problems (like climate change) where 'muddling through' may not drive emergence and diffusion fast enough (Morgan, 2016). Indeed, in the French tram case, strategic orientation allowed for significantly more ambitious interventions than could have been achieved by pursuing a more gradualist path whereby small-scale experiments are introduced ahead of gradual expansion. This point may have wider relevance for debates about accelerated transitions in relation to the climate change problem (Geels et al., 2017; Sovacool, 2016).

Our finding about landmark projects has wider relevance because it suggests that infrastructure projects present particular opportunities for ambitious, radical and purposeful system innovations. A striking feature of French tram projects, notably since Strasbourg (1994), was their framing as integrated transformative infrastructure, implying a systemic approach to intervention (i.e. delivering entire networks as backbone of public transport as opposed to isolated lines), and a head-on engagement with niche-regime struggles (drastic car restrictions, multi-modal dispositions). The implementation of tram systems also had broader transformative effects beyond urban mobility. As tramways became locally enrolled as solutions to multiple problems, they also affected quality of life, urban revitalisation and environmental issues. This transformative potential of infra-systems is particularly relevant in the context of sustainability transitions, which is interested in the depth, speed and scope of change (Turnheim et al., 2015) and emphasises the importance of system reconfiguration as opposed to fragmented, incremental or revolutionary change (Geels et al., 2015).

While our findings have broader relevance, generalisation should be done with care because our case has specificities. In particular, the favourable alignment of French conditions (established tradition of strong state-intervention, nationalised railways, 6-yearly mayoral elections) and enabling developments (devolution, cultural concerns for urban quality of life) remains uncommon by international standards. Nevertheless, we suggest that our findings and conceptual elaborations provide fertile ground for the development of more varied typologies of transition patterns based on challenging implicit assumptions about the sequence of mechanisms and the role of various actors.

Our case also illustrates the importance of early and sustained resource commitments, e.g. national R&D funding, national strategic procurement, and *Versement Transport* (an innovative financial mechanism that ring-fenced a portion of local employment tax revenues for the financing of transport projects). The importance of resource mobilisation and funding has been acknowledged in other approaches, e.g. Technological Innovation Systems (Bergek et al., 2008), but is not yet systematically addressed in SNM. Substantial and relatively stable funding was an important driver of development and diffusion of French tram systems (the feed-in-tariff played a similar catalytic role in the German energy transition). Crucially, this early funding signalled greater commitment than the seed money that is often used to fund tentative experiments. In our case, this stronger commitment relates to the involvement of incumbent actors, the dedicated vision and industrial strategy, and the capital intensity of tram systems. We suggest that future SNM research engages more strongly with issues of funding, and the underlying factors that influence it.

We further suggest that future research could fruitfully explore a more varied set of cases to further (in)validate our claims. These may include 1) examining the diffusion of infra-system diffusion (e.g. modern trams) in different national settings to better understand comparative patterns related to successes (e.g. France, Germany, Spain) and relative failures (e.g. UK); and 2) comparing different strategies for urban public mobility system diffusion (e.g. cycling in Denmark). Together, such analyses could critically mobilise SNM-concepts and develop more differentiated insights.

7 References

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