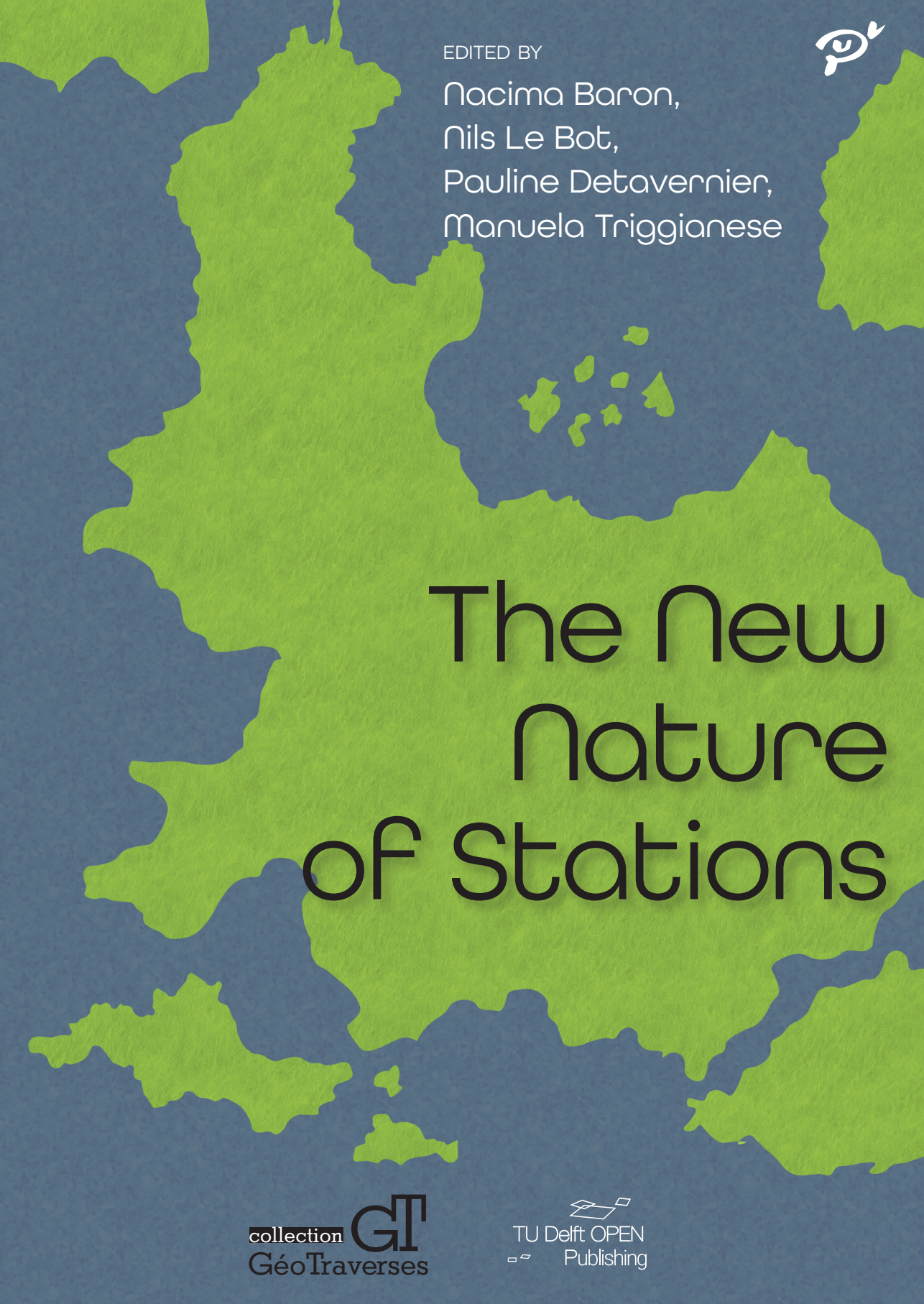

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The New Nature of Stations

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The New Nature of Stations

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Introduction
From modern stations, 'places and networks', to the ecological and metabolic stations of tomorrow

In France, since René Clozier's monumental thesis on the Gare du Nord (1941), geographers have studied these singular buildings because they encompass within themselves two particular spatial properties – place and network.

Studying railway stations across disciplinary fields

Geographers have redefined stations as "network places"

Visit a station in the morning, when it's teeming with people, or at midday, when it seems to be dozing. You will clearly see the essential qualities of place. First because the station always occupies a particular geographical position. It is never exactly in the centre of a city. It will have been built somewhere towards the edge, and this marginality has never quite been absorbed by the urban growth of the last century. Second, because the station is always highly accessible, but at the same time often tricky to access (complicated parking, congested traffic, swarms of buses). Signalled from a long way off on road signs, it sometimes functions as a sort of second city centre, lacking some central functions but possessing others (cafés and snack bars, hotels, car parks, even sex shops). This station-place shares particular traits with other places in the city (the bus station, the airport, the snack bar, the union hall). Geographers very quickly sensed the germinative potential of this place, its capacity to become an environment, because it generates growth around it – railway terraces or office towers depending on the era if you want something concrete, and dreams of every kind if your thing is art and literature.

Topography combines with topology. In the last third of the twentieth century, the "new geographers" came to see their discipline as a science of networks. The dense mesh of the railways provided an ideal medium for building the tools needed to analyse and classify network forms (corridors, radial lines, tangential lines, etc.) and for reflecting, at all scales, on the reciprocal relations of creation (or destruction) between network and territory (tunnel effects and space-time contractions, the barrier effects of networks).

There is a whole body of literature on regional economics and geography that tracks the transformation of rail technology (the French school, in this respect, benefits from the country's early adoption of high-speed rail), since the station, because of its liminal position between the urban and railway worlds, experiences the superimposed effects of rail networks and metropolitan systems. Building a station, and sometimes a new railway line, entails calculating effects in advance or in retrospect (for example, the impact of high speed on the business fabric) and taking into account the sometimes excessively optimistic expectations and representations of the networks of institutional players who anticipate knock-on effects (the "booster" station).

Sociologists and stations as places of movement

This brings us to the boundary between the geographical and the social science approach to the study of railway stations. Stations have been studied intensively from a historical perspective (urban, industrial, technical and architectural history). Are they not closed or isolated spaces, or at any rate spaces that are highly discontinuous with their surroundings, generating alterations in behaviour, deviations from the norm or the creation of new norms, as well as new freedoms? This is the kind of space that Michel Foucault defined as a heterotopia. Outside French theory, with its readiness to explore networks and rhizomes, pragmatist sociology, following Isaac Joseph, began working with the RATP's foresight department in the 1980s to observe what was happening in big-city stations

What emerged was a theory of "movement-places" which emphasised flows, users and ambiences. For their part, anthropologists and sociologists see the station as a place where people pass through and mix, where "solid citizens" rub shoulders with "misfits". Viewed as a hive in which passengers are the bees, the station has since doubled down on its circulatory logic. A miracle and a mystery, it embraces the seemingly random scurry of individuals amid a machine-like chaos that can sometimes seem like a perfectly regulated choreography. Just as with geographers, analytical description is never far removed from a political viewpoint or critical gaze. While anthropologists point to the anomie and mechanistic nature of stations, sociologists flag the role of metropolitan transport in the (re) production of inequalities and in the advent of a surveillance society.

And what about political science? For that discipline, the station offers an instrument of governance as a metaphor not of policy but of politics. A railway station and a parliamentary chamber increasingly resemble each other: the same hurried and harried crowds, the same thermodynamic spectacle (agitation and froth, overheating and a sense of impotence), the same discursive and financial state commitment to the promotion of a fluid society. Why this analogy? The railway station and politics alike still tender the illusion that our world is going somewhere. There are destinations and

timetables on the big board, just as there are promises on election manifestos. And yet politics and mobility are living (or dying) through a time of relentless acceleration and fundamental uncertainty. In the one case, railway stations operate more than ever on a just-in-time basis; in the other, our lawmakers continue to stoke the standards boiler without ever exhausting the sense of urgency about the need to act, with climate change as the sword of Damocles. People buy train tickets in the same way as they mark their ballot papers: a touch of confidence, a touch of doubt...

Engineers and railway stations

A third source of knowledge about stations is the body of material initially compiled by civil engineers in two main domains: design and operation. On the one hand, there is a technical culture based on architecture, civil engineering, urban planning and design. With the emergence of AREP, a specialist agency within the public rail company SNCF, a specific French vision of stations has taken shape, with the forging of typically French concepts such as the "pôle d'échanges" (interchange hub) and theorisation of practices (creating "interior urbanism", designing "capable places"). More recently, the same AREP has embraced the challenge of decarbonisation, economy in energy and materials, and biodiversity, a challenge that we test from a particular scientific perspective in this book.

On the other hand, big changes are also underway in station operations. Station management has always been a science of fluidity, based on the spatial and temporal arrangement of different kinds of traffic (trains, pedestrians), resulting in a juggling of timetables and routes, services and cadences. The engineering that goes with it is engaged in a constant effort to optimise, because network bottlenecks and lulls are costly. These professions share one cardinal value: rail safety. On top of this come all the activities and measures to anticipate the wishes or needs of the "customer-user-traveller". However, everything has become more complicated since the advent of competition and the conversion of the historical players to limited companies. The rail business is shifting (incompletely, and with pendulum effects) from an industrial to a service economy. The job of a station operator is similar to that of facilities manager. Legal, financial, marketing and managerial skills now overlap, compete with and are altering pre-existing technical cultures.

Stations are also the business of architects who, since the first basic boarding platforms, have tried to theorise and characterise the specific urban nature of this fragment of built fabric from an urban design perspective. Oscillating between research on architecture (as an object of study) and architectural research (project-based), designers thus agree in attributing a – partly performative – form of agency to stations, based on considerations

of a symbolic, aesthetic, functional or oneiric nature. This very specific component of the city has been assigned a series of special functions:
– as a signifier (symbolising the presence of the railway, as well as the political and financial power of the rail companies and public decision-makers);
– as a landmark (thus contributing to the spatial organisation of the city, in an approach that is both aesthetic and related to street engineering),
– as a place (to generate economic and social activity, and thus prevent the decline of a neighbourhood, etc.),
– as play a specific role in a network of stations (axis, corridor, star)

Analysed from a functional and morphological perspective, however, the integration of stations into urban or rail networks is not a given, but rather a process of constantly renewed negotiation.

This initial, much simplified overview suggests an initial four-branched compass. On a horizontal axis, the tension between the station as point, place and environment (real or virtual) and the station-as-movement (material and immaterial flows). On a vertical axis, two opposing scientific perspectives. Below, observation, description, taxonomy of stations – in short, a mode of generating fundamental knowledge based on the natural science paradigm, from which geography itself was born. Above, engineering as the production of applied knowledge geared to action (optimising or reforming station operations). This schematic forms four quadrants across which researchers can choose to develop approaches that may be analytical or prescriptive, utopian or critical.

Environmental shocks and epistemic counter-shocks

Vulnerability and resilience of rail infrastructure

Global climate disruption is triggering a series of risks of which railway operators have long been aware, but which are growing in intensity and ferocity and accumulating. Stations and railway lines are highly exposed (risk of sea and river floods, vulnerability of electrical and metal components to heatwaves, uncontrollable wildfires, hurricanes, etc.). These risks (which are only very partially 'natural') are creating threats of a new scale, cascading risks that link the environment, digital technology and energy in complex ways. These risks affect different aspects of rail reliability (technical robustness) and human safety.

Station operators and managers have promised to build strategies of resilience. From being major consumers of electricity, stations will become producers. From being a drain on resources (accounting for between a quarter and a third of SNCF's electricity needs) they will become a source. With their warehouses, sheds and car parks, they offer surfaces suitable for the production of renewable energy, while wind power interests other

operators who develop the land on which the stations stand. In this book, we look at how energy engineering skills are gradually being incorporated into the design or upgrade of stations. We study the growing importance of considerations around the scarcity and relative cost of energy resources. We look at experimental industrial innovation programmes, which are redefining both the station as object and ways of thinking about how to shape this object, place and network in terms of environmental planning.

Theoretical frameworks and modes of expression associated with energy-efficient railway station conversions can vary considerably. At at one end of the spectrum, there are start-ups that dream of a zero-carbon station. At the other, network engineers are looking at infrastructure's contribution to the anthropocene catastrophe, and are trying to make good a kind of moral debt by devising low-energy, low-tech stations. These changes show that knowledge, imagination and emotion do not inhabit entirely separate fields, which is why it is so important to look at them through the eyes of the humanities and social sciences. However, it would be a mistake to gloss over the question too quickly by dismissing the greening of stations as a greenwashing strategy designed to convince people that rail is a low-carbon mode of transport (a claim that is indeed debatable) in order to give operators a clear conscience through CSR (corporate social responsibility). There is some truth to this view, and it is also discussed in these pages, but it is accompanied by other movements that are perhaps less visible, which this book attempts to bring to light. With their talk about frugality, optimisation and the mitigation of environmental impacts, railway engineers are also seeking to break into highly competitive international markets, and take seriously the effort (which is as much scientific as it is economic and moral) to arrive at a new railway ecology.

The potential of *railway (station) ecology*

To speak of an ecological turn for stations or, more ambitiously, to assert the possibility and necessity of a railway ecology that includes a a station-specific component, is a prospect that we ask the reader to explore in terms of its epistemological and ideological frameworks, its conceptual tools, its experimental methods and its implementation strategies. It could be said that this kind of field of knowledge and expertise is founded on two orientations, one (eco)sytemic, the other metabolic.

Firstly, the ecosystemic approach views the railway station less and less as a closed, monofunctional system, and increasingly as one that is connected to other systems (energy, ecology, economics). So, like any built or unbuilt complex of any size, a station can be seen as a milieu (oikos), i.e. an entity that contains species and communities as well as their biotic and abiotic environment. In line with the intuitions that we have seen were already present in geography, the social sciences, architecture and engineering, a station is not a series of default ecological habitats for a few pigeons, rats or crickets.

And it is not natural in the sense that states of nature preceded or succeeded its construction. No, what we are saying is that a railway station, whether rural or urban, active or abandoned, represents a collection of living things and functions like an ecosystem. It can therefore be analysed with the standard tools of ecology: trophic levels, green and blue webs, etc. This book offers a number of points of entry to this perspective. It also emphasises the plasticity of the term "system", because we are convinced that a railway ecology cannot be created without taking into account the socio-technical reality of stations as technological systems and systems of actors.

Secondly, the inclusion of energy issues in the debate on resilient stations opens the door to a metabolic approach. Accustomed to thinking of themselves as the custodians of pedestrian flows or train movements, railway technical services now see the station as playing host to other flows (electrical impulses, data, scorching air currents, migrations of natural species)... This produces genuine cognitive shifts. Previously, these technical actors saw the station as a closed circuit and controlled all movements – pedestrian flows and track occupancy – from operations centres and signals boxes. These days, the station is a place where people come and go in multiple directions, sometimes moving outside ... sometimes not.

The metabolic approach stems from the increasing influence of computational approaches and emission standards (carbon, greenhouse gases). The quest for a station that is frugal in its use of extractive and constructive resources starts from a similar position of identifying and evaluating the quantitative and qualitative inputs and outputs of a station system. The idea is to reuse, restore or offset what is taken from 'nature'. This approach greatly amplifies the scales of analysis and complicates the calculations: from the station building to the neighbourhood, from the neighbourhood to the block (a building or urban heat island), and from the local level to the bio-region, the concept of movement is no longer limited to railway passengers, but encompasses endless nested scales, since thermodynamic circulation and feedback loops operate at a planetary scale. An ecology of stations therefore requires epistemic and methodological breakthroughs, whose challenges and difficulties – and also potential – this book seeks to identify. We have no doubt that through the use of new technical processes (BIM design) and new concepts (frugality, carbon and biodiversity offsetting, prevention of exceptional climate events), the idea of the station will be reinvented, both in its morphology (through closer connection with networked systems: natural habitats, localised social systems) and in its functions (climate role, ecosystem services). This could lead to the emergence of new services (user support, information, safety, comfort, intermodal services – in short, the benefits we owe to the "user-customer-passenger") and other normative realities (the benefits we owe to the client-train operator: energy supply, IT services, living quarters for train crews, etc.).

Thirdly, it is no accident that the practice of station ecology is emerging at this time. In fact, it is an effect of the push for ecological planning in public transport policies as a whole. Similar claims are being made about the decarbonisation of roads and more virtuous airport design methods. However, we argue for the value of thinking specifically about railway stations, even if it means returning to other areas of transport at a later date.

There are two reasons for this. First of all, there are no rails in the sky. The airline industry needs nodes on the ground, but its networks do not need 'infrastructuring' in the same way as the rail industry, which throws up a completely different set of ecosystemic and metabolic challenges. Second, the average airport is fifty years old, while railway stations are often respectable old ladies of 150. The rail world operates on much longer financial lock-in cycles than air travel, and it is connected to quite separate capital circuits, as urban authorities heavily fund the revitalisation of stations as way of boosting entire districts. It is therefore crucial to explore how the station greening movement coincides with an historic moment of reinvestment in the physical infrastructure of the railways: greening coincides with a need for station regeneration, a term that itself has multiple meanings. For a railway architect, the term regeneration refers both to infrastructural modernisation (replacing track and ballast) and to the upgrading of buildings to match them with needs and uses. For railway economists, the attribution of significant financial resources is now a pressing necessity. These funds are needed to recapitalise obsolete rail networks, a number of which have been permanently decommissioned, while others have been reopened, albeit at the cost of considerable regional or local sacrifices. Two chapters in this book address this issue in detail. One elucidates the role of stations as a pivotal element in anchoring expectations of value creation among major public and private investors, which are concurrently adopting an ecological position through green securitisation. The other shows how the revival of a station can help a rural politician to tackle simultaneous infrastructural and ecological challenges in his region.

The use of stations thus allows for a collaborative exploration of the concept of cyclicity from the perspectives of railway economics and railway ecology. The term used to describe this joint approach is "refreshment". A more ecological approach to stations will maintain their viability in climatic conditions that we we cannot yet predict accurately, but which worry us, such as heatwaves (the subject of a chapter in this book). Another sense of the term "refreshment" refers to the greening that accompanies station redevelopment: this is the idea of refreshment employed by the building industries, renovation without transformations to the built structure. There is no doubt that ecological planning will do much more with buildings that are already there than with architectural prototypes (another chapter opens this discussion). Finally, in the everyday sense, we talk of refreshing – i.e. updating – a web page. Understood

in this way, a refreshed station is one that is back in phase, reconnected with current flows of knowledge, skills and legal-technical conditions.

The book's intra-and trans-disciplinary ambitions

This book is a valuable contribution to the Géotraverses collection, as it demonstrates how a subject that has been extensively studied by the geographical community can benefit from interdisciplinary engagement, leading to new insights and new avenues for exploration.

These avenues exist within geography. Our approach to railway stations reflects the particular positioning of geography at the interface between the natural and social sciences. In addition to the geography of transport in the strict sense of the term, this book is addressed to researchers in climate geography and biogeography, and we hope that it will enhance intra-disciplinary links. For those engaged in the field of geomatics, it demonstrates advances and potential innovations, both conceptual and methodological, in the domain of modelling (for further insight, see the chapter on green transit-oriented development). For geographers of social phenomena and specialists in urban and territorial studies, it shows how research on infrastructures can embrace clinical and critical considerations of subjective experience or corporeality ...

This book also has interdisciplinary ambitions and calls for geography to join forces with other fields (architecture, urban planning, development, economics) as well as with the network sciences of rail and digital engineering. This is why, in addition to the fairly traditional use of interlocking scales of analysis with which geographers are familiar, we have chosen to highlight work that draws on two domains of theory.

The first of these is the analysis and mapping of network actors and their organisation into multi-level systems. This approach provides tools for conceptualising and representing the interactions between the many living and non-living "things" that are and constitute stations and that enable us to move from the station as network node to the station as a network of networks.

The second domain relates to the socio-technical approach to infrastructure, a field in which the railways already occupy a prominent and long-standing position. This book is part of the shift towards an eco-socio-technical approach, in other words, towards a way of thinking that incorporates the various forms of transition (energy, urban, etc.) and asks questions about the meaning and direction of these transformations. Transition is seen as a path, which means that the role of stations can be situated within ideas about adaptive pathways. The energy transformation of stations can be studied via the idea of niches that spread – or fail to spread – experiments within regimes of innovation. This approach places the newly 'greened' stations at the interface between

regulatory changes, organisational processes, regional dynamics and many other factors where questions of knowledge and power are central. We believe it is essential for geographers to add their voices to this political ecology of innovation and to be present in the circles where they can contribute their knowledge of the infrastructural legacy (the history and spatiality) of rail networks, their contemporary state (deterioration, obsolescence, formal and functional diversification), and their future.

Structure of the Book

The first part of this volume explores the interactions between railway stations and the biosphere. It contains chapters that consider exchanges between living realities outside the station (for example natural habitats, Auvray et al.). Research has identified relationships that are both positive and negative for the quality of the environment or for station functionality: for example, railway stations and networks are well-known barriers to species migration, but rail corridors can in some cases serve to enhance mobility for other animals (Auvray et al.). Some studies show that network production has, over time, shaped certain sites that we see as natural (e.g. the railway forests of Japan, Tiry-Ono in this book). This section includes the question of the social and cultural perception of markers of artificiality or naturalness in stations.

Through contributions that focus on the reuse of excavation spoil, or the recovery of rock removed during the digging of underground stations (Cherkaoui El Baraka), the second part highlights engineering's renewed interest in a more frugal use of natural resources. Once again, we have been careful to emphasise the extent to which this type of practice is both a part of railway history (Detavernier and Striffling-Marcu) and, at the same time, entails a radical change in the way stations are designed and modelled (Le Bot). This shift is not taking place everywhere, nor is it integrated equally into the economic or regional strategies of railway companies. Depending on the case, existing normative factors and professional practices provide resistance, barriers or support for the incorporation of innovations into conventional station production processes. Much of the work to be done lies in the socialisation and institutionalisation of innovations and collective learning.

The third part looks at the station environment from the point of view of re-greening and landscape integration and emphasises the sensory qualities of stations. We have taken care to shift the focus away from subjects that are perhaps more familiar, such as the integration of stations into the landscape of protected natural sites or the presence of flowers and plants in passenger buildings. However, we have made two choices. One is to select work that challenges the omnipotence of the visual dimension, thus opening the way to a more eco-phenomenological approach (ambiences, atmospheres). This

is why this section includes an exploration of station soundscapes and their effects on social inclusion or discrimination (Carcano). The second choice is to value the subjective dimension of the term landscape and to focus on the conversion of stations into future value, which opens up other connections between ecology, design and market forces (Riot). On this subject, we include a chapter on the financialisation of stations, another on transit-oriented development and the serial greening of stations (as part of a metropolitan corridor), and yet another on the translation of material objects present/absent in a station into traces in a digital ecosystem (Rezanova).

The fourth part recalls that people, both as individuals and groups, are at the centre of the new nature of stations: the busy and discontented user as well as the ever rejected homeless person (Voiseux). Design engineers in their laboratories, full of fine intentions, and railway workers at the bottom of the ladder, sometimes caught up in the contradictions of management. The politician, protector of a fragile territory who dreams of revitalising an abandoned station (Ferretti et al.) or the artist, fascinated by aesthetic potential of the ruined station overrun by nature (El Hage). In this section, we have brought together all these voices to show that an ecology of stations would be about much more than technologies alone (Veloso E Zarate and Triggianese). It would mean engaging scholars and decision-makers for the long term, without which there can be no sustainable foundation for our lives as mobile city-dwellers.

Part 1.

Ecologies and Networks

The biodiversity of railway station districts: Socio-ecological systems and multilevel networks

Alexandre Auvray, Yohan Sahraoui,
Nils Le Bot and Pascal Marty

The railway station is a technical object (Baron and Roseau, 2016), a component of urban space that is inherently hostile to biodiversity: it is an accumulation of technical and functional constraints that make it a highly artificial and controlled space. Any urban ecological habitats in it where species could spend part of their life cycle are rare, poor in quality and possibly polluted (Galopin et al., 2021). In addition, the areas of vegetation located within the railway footprint (embankments and wasteland) are difficult to access for animal species that might colonise them. The large number of technical infrastructures (e.g. fences, road intersections) represent impassable barriers for many species.

And yet, at both landscape and neighbourhood scales, stations could contribute to urban biodiversity and thus bring many benefits to humans (Zari, 2018). In fact, some stations have disused land with significant ecological potential, or man-made features that could encourage biodiversity (insect hotels, for example). While stations may have local importance for biodiversity, their integration into an ecological network is fundamental to the resilience and sustainability of communities of animal and plant species.

For this to happen, a change in planning and management practices for station areas is needed, particularly their green spaces. These changes relate to a more global concern with the place allocated to nonhuman life in the city. To understand how these changes might take place, we can think in terms of an environmental problem (Mermet et al., 2005). The station might be seen as an ecological object that is lacking adequate quality in the eyes of at least one of its local stakeholders. The latter takes ownership of the problem and then tries to influence the practices of other stakeholders who have an influence (positive or negative) on the biodiversity of the areas they control within the station. Under these conditions, the environmental problem becomes a problem of governance (Young, 1999), bringing into

play a variety of sometimes intimate relationships between humans, space, plants and animals.

Increasing the contribution of stations to urban biodiversity requires to consider the relations between humans and nonhumans. However, the presence of wild species in towns and cities creates certain tensions, particularly when these species do not have a favourable public image and encroach into residents' private spaces (Capon, 2022). This opposition between domestic and wild and between nature and culture, is based on what some anthropologists have called 'naturalism' (Descola, 2005). This ontological divide in thinking makes it difficult for new relations to wildlife to emerge, especially as there are many factors that produce and reproduce it: institutions, technical objects, etc. However, this conceptual framework does not dictate everything: in the real world, there are many opportunities for bonds to be forged outside this dual conception. For example, thinking of the wild as an asset rather than as an "other" that has no place in the city makes us more inclined to adopt practices that welcome it. Extended to a larger scale, these more intimate relations with wildlife could become the basis for a "biodiverse" city (Clergeau, 2015).

To study these relationships, we propose an analytical framework based on the concept of networking. The first advantage of the network is that it can encompass entities of different natures (Latour, 2005) without making a priori distinctions between them. This type of approach has been very useful in the study of problems that involve humans and nonhumans in various disciplines. Examples include the study of trophic networks (food relations between species) in ecology, or the study of social networks in sociology.

Most of the big issues relating to biodiversity around railway stations have a spatial dimension. Through the network approach we can address this dimension by modelling the structure and layout of the built and unbuilt environment, and their connections with ecological processes. Landscape ecology, a discipline at the interface between ecology and geography, links together spatial structure and ecological processes. It stresses the importance of the composition and configuration of space for the various ecological flows that run through the landscape. Moreover, landscape and ecological systems coevolve through feedback loops that depend on spatial parameters. Lastly, spatial configuration and social processes exert a reciprocal influence. Formalising these elements via networks helps to analyse these mutual interactions. The spatial arrangement (scale, territorial distribution, etc.) of governance institutions relative to the ecological processes for which they are responsible has been the subject of recent conceptual proposals, such as the landscape ecology of institutions (Cumming and Epstein, 2020). The use of a network-based analytical framework to study the interface between the ecological and social dimensions of stations would therefore seem appropriate.

The aim of this chapter is to show how conventional frameworks of governance – such as those of railway stations – struggle to include nonhuman actors. We use an example to illustrate the importance of such an inclusion. Lastly, we will develop our analytical framework by situating – within networks and in space – the different stakeholders present in the vicinity of stations.

Some theoretical foundations

The concept of socio-ecological systems (Levin, 1999) emerged from studies on environmental resilience. It takes into account the complex, non-linear interactions between human communities and ecological systems (Folke et al., 2012). One of the objectives of this conceptual framework is to determine the sustainable forms that human institutions dealing with natural resources can take (McGinnis and Ostrom, 2014).

Not everyone who lives near a station values the presence of biodiversity, and those who do value it do not necessarily do so for the same reasons. The presence of a protected species may, for example, occasion a sense of wonder in an individual's private garden, whereas it will represent an additional cost item on a station development site. These relationships between humans, animals and plants are not just utilitarian. They are intertwined, entangled and subject to constant negotiation.

The second difficulty with socio-ecological systems is that they are rooted in social network theories, which limit the notion of the social to humans alone, without any mediation by 'things' (Latour, 1990). However, certain nonhuman entities (living or inert) – including the station itself – exercise considerable influence. They act upon and transform other elements. So the focus needs to shift from collaboration between humans to the 'things' that mediate that collaboration. They are more than just biophysical or contextual factors – they play their part in controversies and activate each other.

Actor-network theory follows the principle of generalised symmetry. It remains agnostic about the capacity of entities, whether 'natural' or 'social', to act or suffer. The actor is thus defined as "any element that seeks to bend the space around it, to make other elements dependent on it, to translate wills into the language of its own will" (Translated from Latour, 2006).

When it comes to managing green spaces, the station is an actor. It possesses agency, a "power to act", which in the case of the station in particular is manifested as its tendency to translate fauna and flora into risk factors for its operation. The station partitions the world, assigns specific roles to human and nonhuman actors and permits or excludes certain uses (Akrich, 2010).

Station agency and the environmental problem

With regard to the environmental quality of station districts, AREP (a subsidiary of the French national railway company SNCF) has designated itself as the holder of the biodiversity issue in railway stations areas through the FRUGACITE action-research project (Marty et al., 2020). The purpose of this project is to determine how elements of biodiversity can be incorporated into localities with severe technical constraints. It focuses on four station districts on line N of the Transilien railway (Île-de-France), arrayed along an urban-rural gradient: Gare Montparnasse, Gare de La Verrières, Gare de Rambouillet and Gare d'Epône-Mézières. Three participatory workshops were held to explore the relations between the stakeholders (SNCF personnel and private property developers). All the participants were asked to define the components of an archetypal station district, its technical constraints and the potential diversity present. Three sets of questions were asked (table 1).

With regard to the composition of the station district, the answers highlighted the station's physical agency on the area: passenger buildings, place names, fences and linear elements all point to the ways in which the station changes the biophysical environment. Participatory workshops also identifiy the agency of the railway station when considering the technical constraints to be taken account for its functioning (attracting users, serving the public, people with reduced mobility, safety, regulations). On the question of biodiversity in the station, the answers showed that the station's agency is manifested in two ways. First materially, in its impact on the ecological environment and populations, in terms such as: reducing anthropogenic pressure on embankments; anthropogenic facilities designed or not to accommodate biodiversity (beehives or litter bins, for example); then conceptually. Because the station would incorporate animal and plant species into the existing technical systems, biodiversity was seen as a constraint with respect to safety factors (large animals, weeding of tracks), or the need to arrange spaces in order to influence user perceptions (no unmanaged vegetation in order to give an impression of tidiness). It is difficult to change the ideational agency of the station by challenging the priority assigned to the technical system relative to other issues such as biodiversity. Its operation is too well organised by other nonhumans, in this case by technical standards (AFNOR NF X50-100 and NF EN 135). These standards function as if the station had delegated its agency to them alongside service functions. Passenger transport (service), for example, depends on safety guaranteed by compliance with (technical) standards, and the presence of vegetation is unacceptable because it could cause a derailment (Bruyas, 2015). The logical connection between elements in this system is based on hierarchy and specification.

Table 1: Questions and answers from Participatory Workshop 1

Questions	Answers	
Can we find the station district through the forms of the buildings?	Confrontation between the pacified urban world and the industrial world (cables, IPN beams, noise, dynamics, industrial buildings, etc.). Diversity of activities and buildings. Fencing and linear elements (tracks, rails) causing an urban break. Signage (especially in rural stations). A space opening at the level of the forecourt. Voyageur heritage building (despite new, less recognisable designs). Flow and stagnation of individuals. Toponymy. Parking and bus station. A potential imbalance between parts of the station district underlined by the absence of identifying elements on one part.	
Spaces with strong technical constraints: what technical constraints are we talking about? Which ones are specific to stations?	Non-station-specific constraints	Pollution due to heavy traffic. Presence of industrial sites because it is an attractive site. Reception of the public: Accessibility (People with Reduced Mobility, etc.); Static density. Presence of waste. Site management and maintenance. Water management (forecourt impermeability)
	Station-specific constraints	Water management in a very mineral forecourt. Superimposition of constraints because of the superimposition of services (shopping centres, flows, etc.). Density: density of the building and space available for development; Static user density in urban areas. Networks and flows: convergence of complex networks; vehicle traffic; density of flows in urban areas; security problems related to the density of passenger flows; convergence of flows through the station as an attractive hub and bridge between two discontinuous spaces. Maintenance and management of a secure site. Noise and noise pollution. Securing rights-of-way. Accessibility and crossing a safe linear space.
What is biodiversity in the station? Does it carry negative or positive values?	Negative	Avifauna (pigeon, magpie); Rats; large fauna on the rails; Asian hornet.
	Both Negative and Positive	Spiders; Snakes; Flora but presence of invasive alien species.
	Neutral	Small fauna (hedgehog, mouse, etc.); herbaceous plants/urban meadows on the shoulder; wall lizard; Trees in hanging pots.
	Positive	Shelters/Green roofs; Valleys; Landscaping; beehives above the passenger building; Poppies; Ornamental flower boxes.

This is the advantage of infrastructures: the links between system components are extremely stable, highly interdependent and involve a large number of nonhumans, notably in the form of standards. It is therefore almost impossible to renegotiate the station's identity in order to introduce a new nonhuman element – i.e. biodiversity – without disconnecting previous links. So there are two choices... The first is to find a solution that permits the presence of biodiversity in the station without coming into contact with the technical operations network. In other words, to create two parallel worlds, interwoven but non-communicative, one for the station and the other for biodiversity. The second choice is to think in terms of cohabitation, i.e. stations and biodiversity taking the risk of living together.

Biodiversity in stations: networking the different actors

These considerations offer prospects for modelling the socio-ecological systems by combining social network theories with theories from the ecological sciences. These formalisations have been developed to connect the spatial, temporal and functional dimensions of ecological processes and, in particular, to address issues of scale and coordination in governance systems (Ekstrom and Young, 2009).

Some authors model socio-ecological systems as multilevel networks (Bodin and Tengö, 2012) (Figure 1). Social entities and ecological entities are formalised as nodes. Social entities can represent human institutions at different scales, from single individuals to international organisations. Ecological entities can represent species, communities of species, natural habitats, etc.

– The flaw of these models is that they reproduce nature/culture dualism by restricting the social element to humans alone, but they limit this divide by representing social or ecological entities in the same way. These nodes are divided into two distinct levels according to their nature, and there can be links between each node, including links of different natures (intermediate level). In the same way, the relationships between human and ecological entities are conceptually distinct but represented in the same way, as links. Links between social actors can be formal or informal (power relations, mutual interests, etc.).

– Links between ecological entities can represent any type of relevant ecological flow (animal movements, for instance).

– At the intermediate level, the links between human actors and ecological entities are referred to as "socio-ecological interdependencies". They formalise the different ways in which social actors take responsibility for ecological entities.

Here we find the dual limitation of these binary frameworks. First, the relationship between human actors and ecological entities is purely one of control; humans can only be masters of nature. And second, social relations between humans are exempted from the mediation of things, which are automatically denied agency. But it is the status of the actors themselves that is central to issues of governance.

The determination of who is and who is not an actor in the biodiversity problem arises from negotiation by the various stakeholders in the problem and not from a contextual element (Callon and Latour, 2006). While some nonhumans act as intermediaries without altering what they mediate (for example, the station information board), others act as mediators, changing the identity of things. A contract that delegates the management of green spaces, for example, contributes to defining or redefining the identity of a station.

The physical agency of the station on wildlife, which is manifested through the impact on species' living environment, can be included in such a framework. The presence of ecological habitats is central to the life cycle of fauna: feeding, reproduction, etc. Some amphibians (e.g. the common toad Bufo bufo) require the presence of aquatic environments which may be

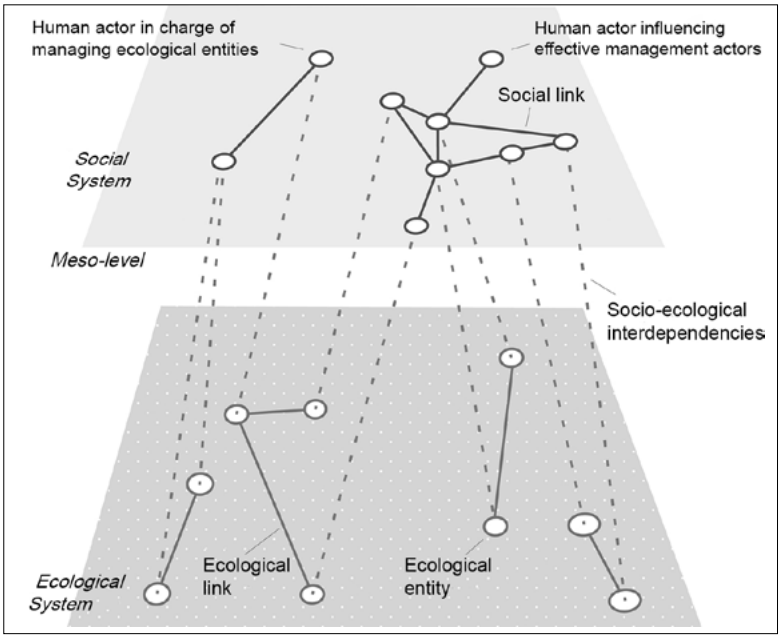

Figure 1: Modelling socio-ecological systems as multilevel networks

eliminated or rendered inaccessible as a result of of discontinuities created by the railway line.

Landscape connectivity, a key concept in landscape ecology, indicates the degree to which landscapes facilitate or hinder the movement of organisms between the patches of habitat in which they pursue their life cycles (Taylor et al., 1993). Assessing this property of landscape is fundamental to understanding the impact of the station on the survival of animal and plant communities. In station districts, habitats are few and far between, and the landscape is fragmented by urban development and linear transport infrastructures. Species therefore have to venture outside their ecological habitat and pass through landscapes that to some degree hinder their movement. Each species, depending on its physiological traits, will vary in its ability to cross a given environment; a bird, for example, will find it easier than a large mammal to cross a suburban environment.

From this perspective, the station can be seen as an assembly of architectural objects with their own landscape resistance: the presence of recessed platforms, the planting of green outbuildings or the presence of lights that affect nocturnal animals. For example, fencing erected along railway track for several kilometres on either side of stations will act as a regional scale barrier for some species, preventing them from reaching habitats that are geographically close but inaccessible in practice. This landscape fragmentation ultimately leads to the genetic impoverishment of populations, and may even bring about their extinction. However, the existence of technical solutions such as wildlife crossings can partially mitigate this effect.

Landscape connectivity can be assessed using ecological network models based on graph theory, which is particularly relevant in our case. Modelling with landscape graphs (or habitat graphs) (Urban et al., 2009) uses spatial landscape data along with information on the species' ecological traits: habitats, dispersal capacities, etc. (Foltête et al., 2012) (Figures 2a and 2b). A graph specific to a given species is constructed from a landscape map. Different landscape resistance values are assigned according to land use, according to whether they facilitate or restrict the movement of species. The ecological network represented by a graph thus consists of habitat patches (Figure 2b) characterised by their ecological quality. These patches are represented in the form of nodes and connected by itinerary lines that follow the corridors along which animal movement is possible. Two patches are linked if the model predicts that a species can move from one patch to another. Landscape graphs have proved their operational value in assessing the impact of development projects, ecological restoration or compensation operations (Foltête et al. 2014), or in setting up ecological networks (Sahraoui et al. 2021).

These kinds of methods are used to identify green-blue grids at station district scale. They offer a way to assess, for example, the impact of including planted areas in the station forecourt, the impact of artificialising the

land through the urbanisation of the station neighbourhood, or the fragmentation caused by the erection of fences.

This kind of modelling also has a performative effect. It alters the links between actors in the train system, it demonstrates to certain stakeholders that the station is a strategic space within the regional ecological network and a vector for sustainable territorial development, not just a technical object.

Adapting the framework to our environmental problem

Formalised in this way, the ecological network can be transposed into the multilevel network model, forming an ecological sub-system enabling us to represent and assess landscape connectivity.

The social entities placed opposite the ecological entities must also be determined. Transposed to our environmental problem, this means all the actors able to modify ecological habitats. These changes can take the form of additions, erasures, or increases/decreases in ecological quality: adoption of virtuous management practices, pollution, etc . The model also contains the other actors involved in the problem, whether or not they play a role in managing the space. These may include nature groups, which also help to change the relationship between managers and the areas they manage.

To complete this framework, the nature of the links between the various entities needs to be examined. However, the limitations of the classic multilevel network framework mean that the formalisation has to be changed twice. First, because there is no inherent difference between ecological and social entities, we have to treat the links in the social system and interdependencies in the same way. Second, reintroducing the impact of things changes these direct links into branches that involve nonhumans. For example, in the interdependence between the station developer and the space developed, we can now identify the presence of the station. In fact, during the participatory workshop, we saw that the railway station stakeholders translated species into their own language: large fauna pose risks of collision. Interdependence is no longer just a matter of taking charge, but of ‘living with’, involving humans, species, spaces and nonhumans.

It is not just interdependencies that become branches mediated by things. The same happens to relations between humans. To take the example of the station again, it designates which people, field personnel and managers can legitimately speak on its behalf. To be a “spokesperson” for the station, you need to be able to track the station network, to know how to organise nonhumans (technical services and constraints) as “requested” by the station. A perspective then emerges. It does not require analysing all the nonhumans implicated in relations between human entities, between ecological entities, or in interdependencies. This would require tracing the networks of

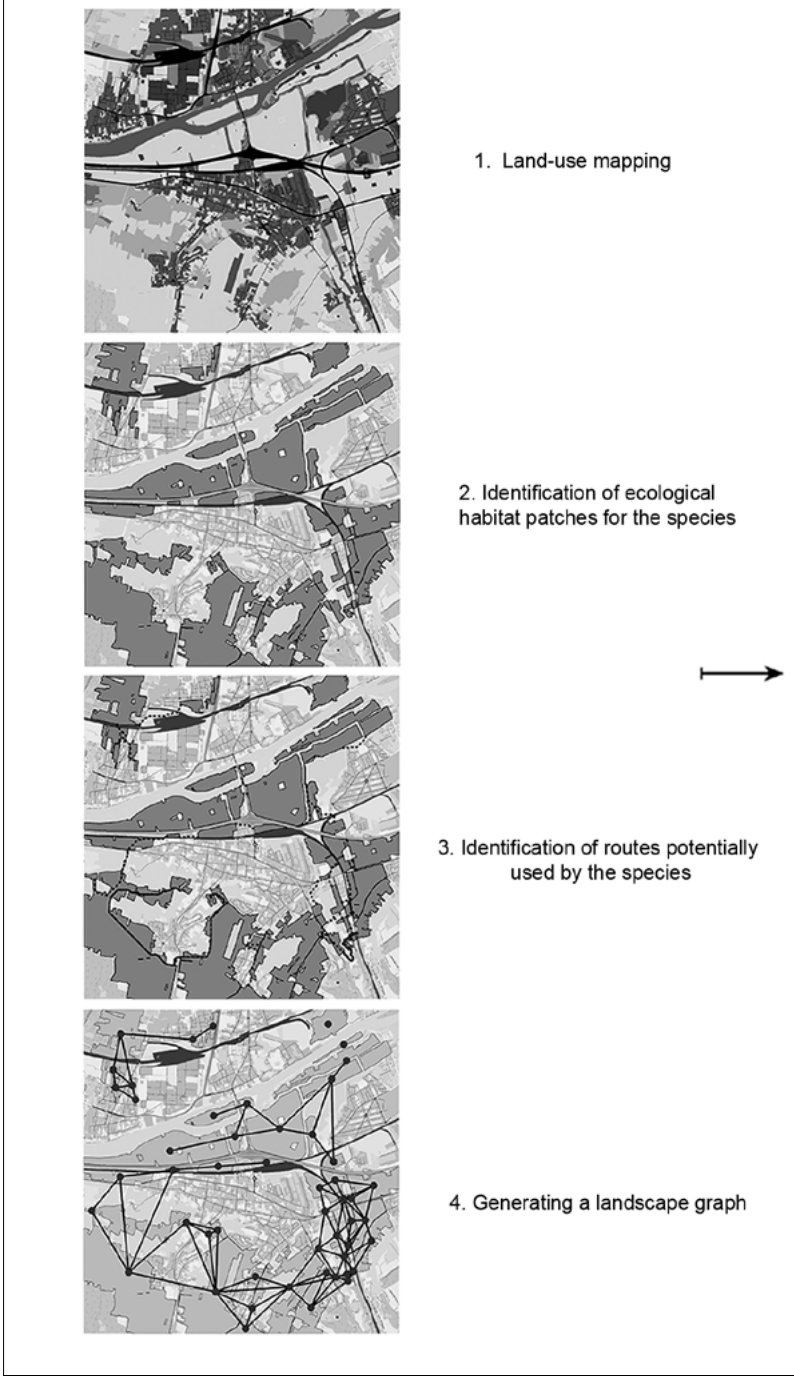

Figure 2a. Stages in the creation of a landscape graph for the wall lizard

@ A. Auvray, Y. Sahraoui, N. Le Bot, P. Marty.

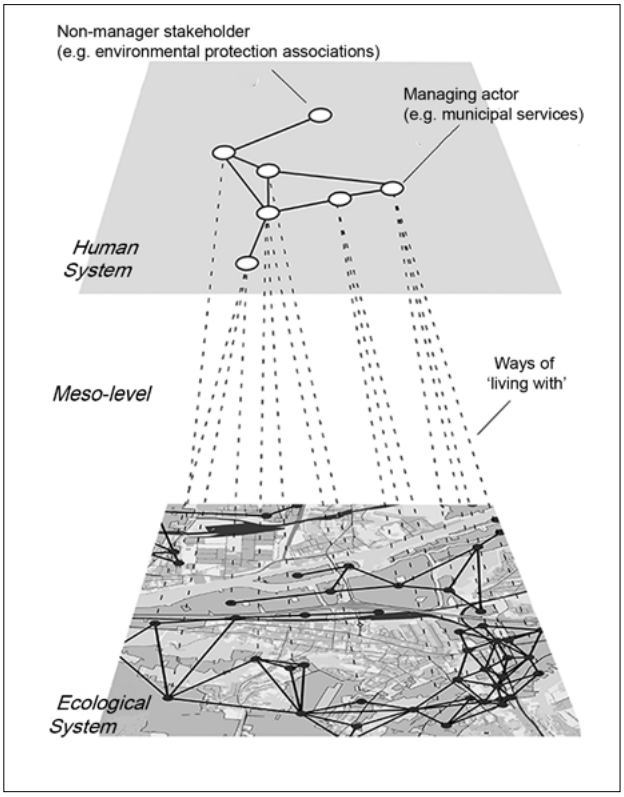

Figure 2b. Integration of landscape graph into multilevel framework

@ A. Auvray, Y. Sahraoui, N. Le Bot, P. Marty

an extremely large number of objects, processes and institutions, from the train ticket machine to genetic drift in the animals. The aim is to identify only those objects that will be involved simultaneously in relations between humans, in interdependencies and in ecological relationships.

In a second step, as the station is one of those nonhumans. we need to understand what impact changing such an object may have on all the actors involved in such a complex network. For example, landscape graphs can change the identity of the station and highlight the station district's potential strategic impact on biodiversity. We need to study how operators appropriate these results and their consequences, as other studies have done for road infrastructures (Bourgeois et al., 2022). Conversely, it is helpful to study the impact on the ecological network of the appearance of new nonhumans that mediate social relations. The participation of station professionals in discussion groups about best practice could potentially have an impact on landscape connectivity. Finally, the spread of a new interdependence between an actor and their space can have consequences for the social network (dissemination of practice) and the ecological network (increase in the ecological quality

of environments, and therefore landscape connectivity). These changes in the multilevel network can then be analysed by a combination of quantitative methods (e.g. ecological connectivity metrics based on graph theory: centrality, intermediality) and qualitative methods (ethnographic interviews, historiographic analysis, etc.) (Nimmo, 2011).

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In determining the conditions under which biodiversity can be introduced into a station district, the multilevel approach we have developed eliminates two difficulties. The first is the view that humans are the sole players in the management of these areas, granting them both too much importance and too many responsibilities. The second is the reduction of human beings to rational agents who can only implement an utilitarian vision of what falls within their responsibility. The main advantage of the analytical framework we have presented is that it brings together human and nonhuman actors, while making explicit the relationships between them. It means that the agency of nonhumans is not automatically dismissed, while at the same time highlighting the agency of the station itself.

The conceptual framework we propose thus offers two complementary analytical pathways, namely the analysis of material agency and the analysis of the ideational agency of all the actors involved in the problem. The first corresponds to a study of the station locality's landscape connectivity. Modelling based on graph theory enables us to identify the key players for the different species; for example, the station, whose architectural structure may represent an obstacle (fence) or an opportunity (wildlife corridors). The second approach entails studying the relationship between human actors and the biodiversity of the station district. Each actor has the possibility of calling upon the nonhumans that they believe to be relevant in explaining their choices and practices.

These two analytical approaches can be combined using multilevel network representation. By developing comparative, diachronic or multisite approaches, we can study how the station's material agency influences its ideational agency, and vice versa. The analysis can be extended to any human or nonhuman that intervenes in the environmental problem through physical or ideational action. In short, this framework converts the problem of collaboration into a problem of cohabitation. The purpose now is to understand all the possible ways in which human actors can "live with" their environment.

Nonetheless, there are a number of limitations to this approach. On the one hand, it may be counter-productive to reintroduce nonhumans ideationally into a model that separates them into 'social' and 'ecological' systems (Mugerauer, 2010). Furthermore, while connectivity modelling is a powerful analytical tool, it leaves the agency of the species themselves

to be explained by a model. It does not allow the researcher to take ontological risks, and reproduces the control of the human over the nonhuman (Hinchliffe et al., 2005). These limitations, which are inherent in all modelling, can be minimised by remaining open and attentive to the actual terrain and biodiversity as it exists on the ground.

When train stations poured fumes into the city: Railway smoke abatement, a matter of 'hygiene, cleanliness and aesthetics' (France, 1830-1930)

Arthur Émile

> "The traveller who climbs aboard a fast train in winter to reach the delights of a distant Riviera [...] evidently finds it hard to understand all the exorcisms that the railway occasioned in its hesitant beginnings [...]. In retrospect, the arguments deployed by the detractors of the fledgling railways seem as preposterous as they are disingenuous. Was it reasonable, in condemning the construction of stations, to adduce the consequences that would result from [...] the poor hygiene of the railways for the unfortunate 'natives' who would be suffocated by the smoke belched out by infernal locomotives!"
>
> Marcel Laurent, " Haro sur le Progrès ! ",
> *Le Petit Troyen*, 18 July 1924.

Since the end of the nineteenth century, the advent of the railway in the landscape and in society has been the subject of numerous anecdotes, which – whether intentionally or not – had the consequence that fears of a medical or environmental kind were dismissed in favour of a now well-oiled technophile rhetoric: "Just as past fears seem absurd to us, present fears will seem ridiculous to our descendants" (Fressoz, 2012). Far from enjoying the welcome it deserved, the train is said to have been the object of unfounded prejudices, particularly when the first stations were being built. This "reaction" from public opinion made the success of the railway and the great heroic narrative around it all the more striking. People were worried in particular about the noise and smoke produced by the locomotives, and about the fires they might cause (Jarrige, 2014). Looking at the socio-environmental consequences of railway operations, it is hard to conclude that these fears were as ridiculous as they are still presented to us today. In the era of steam traction, air pollution and fires caused by the burning of coal, for example, sparked neighbourhood conflicts that challenged the acceptance of the rail industry in various places (Émile, 2022a, 2022b). In the particular case of smoke, these conflicts broke out first and foremost in

urban areas, where the passenger station was perceived ambivalently as "half-palace, half-factory" (Schivelbusch, 1990). It is this second aspect that we propose to develop.

Although studies of railways in the city focus primarily on stations, which are often confounded with passenger buildings, their conflictual relations with their neighbourhoods are not often addressed (see Nilsen, 2008; Sauget, 2009, 2018). In this chapter, we will look at their impact on the city through the prism of the smoke emitted by steam locomotives from the earliest structures to the electrification of urban lines. By viewing the station as a 'transport factory' – to borrow an expression used at the time of the establishment of Orsay Station in Paris around 1900 (Notarnicola and Poupardin, 1992) – and hence as a source of tension with its urban environment, our aim is to reveal the harmful component of an activity whose presence in the city was associated with both the benefits and the drawbacks of industrial modernity.

By "passenger stations" we mean not only the main buildings, but also the other facilities on the same site required to operate the railway. Railway sheds in particular could contain several dozen locomotives, which would take hours to heat up, producing copious amounts of black smoke. From the second half of the nineteenth century onwards, the concentration of traction and shunting machinery in main railway stations represented a source of air pollution comparable in some respects to that of an important factory.

The main buildings themselves could be described as palaces of industry: the outward part that looked towards the city had an attractive façade and interior spaces inspired by official architecture; the inner part was a hive of intense industrial activity. In major stations, for various reasons, the large halls that protected passengers from the elements as they embarked or disembarked formed the transition between these two dimensions, the visual seam between the urban and industrial worlds. Their architecture reflected this hybridity, with dimensions that expressed not only the desire to impress the public or to accomplish an engineering feat, but also the need to evacuate the smoke that rose and accumulated under the vaults – "skies of cast iron and glass and soot", wrote Verlaine (Tantalized, 1889) – before dispersing through the skylights running along the roof ridge. The fumes that spilled over from here into the city betrayed the industrial nature of the station, despite the architectural efforts made to embed them within the urban fabric.

The historical study of smoke as a material and sensory object reveals a wide range of perceptions that are temporally, spatially and socially situated. However, as smoke became an increasingly intrusive phenomenon, the objections to it grew. Initially ignored or dismissed, the complaints of people living near stations preceded the gradual recognition of the railway's contribution to urban air pollution. At the turn of the century, journalists

and local councillors were reporting growing discontent, accentuated by the emergence of alternative modes of transport in a global context of opposition to industrial fumes in cities (Émile, 2021).

This chapter looks at how this pollution shaped perceptions and discourse about the station in France. In the first part, we show how train smoke became a source of neighbourhood conflict in urban areas. Then, in a second phase corresponding to the development of electricity as a vector of energy, we will see how the debates over air pollution crystallised tensions around railway stations in different domains, relating to health, hygiene and urban aesthetics.

A "transport factory" in the city
First spills and urban conflicts

The installation of railway stations in close proximity to homes and human activities drew immediate criticism because of the harmful effects, real or supposed, attributed to this type of activity (Caron, 1997; Sauget, 2018).

Figure 1 - Raoul André Ulmann, La Gare, 1902, oil on board, Bayonne, musée Bonnat-Helleu, inv. CM 125

Although this was only a relatively secondary aspect of the debate, particularly compared with economic considerations, it occupies an important place in people's perceptions and recollections around the early days of the train.

The negative externalities associated with the burning of coal, in particular smoke emissions, were already well known to contemporaries familiar with steam engines, and triggered an array of local effects that sometimes raised concerns. There were several reasons. Some owners worried about the impact on the value of their properties (Sauget, 2018). Potential neighbours expressed worries about their living conditions, for example the smell of coal smoke, but also noise pollution and the aesthetic impacts (Corbin, 1983). Finally, certain agricultural and craft activities were considered potentially incompatible with proximity to steam locomotives, which resembled "mobile factories" (La Science et la Vie, June 1925). While the arguments might be deployed opportunistically to support or dismiss a particular route or station location, they show that these concerns had acquired a certain legitimacy. It is worth noting that frequent petitions were circulated in support of the establishment of a local railway station, partly motivated by the fear of falling behind a neighbouring locality (Caron, 1997). These economic considerations and the desire for a local train were not incompatible with the awareness of negative impacts, whether anticipated or revealed in hindsight, or even with expressions of dissatisfaction. Most conflicts therefore revolved around the degree of intensity that would be deemed acceptable (Émile, 2021).

As with other public projects, the construction of railway lines and stations was preceded by enquiries held to publicise information and to assess public opinion in a controlled manner. In the early nineteenth century, the public enquiry might be seen as a "political technology that was employed both to improve plans and to manage objections" (Graber 2016). From 1841 onwards, railway development in France was facilitated by the fact that all railway projects were considered de jure to be in the public interest. This did not preclude sometimes heated local debates on the future route of the lines or the location of the stations. These might involve as many as several hundred petitioners – mainly property owners, artisans and shopkeepers – who might concur with or oppose the views of the local authorities (municipal and county councils, chambers of commerce). These petitions show the different perceptions around railway stations, and some cases reveal concerns about its industrial nature. For example, around 1835, the plan to establish the terminus of the Paris to Saint-Germain line on Place de la Madeleine immediately triggered concerns and objections on the part of certain property owners on the grounds – among other things – that the aesthetic damage to the district and local environmental impacts were likely to undermine the value of their properties (Lecoy, 1992; Sauget, 2018). The issue was taken up several times in the Journal

des débats politiques et littéraires, which published the arguments on both sides, and Le Magasin Pittoresque openly derided the objections raised by some of the project's opponents, seeing the issue – as in the British case – as a matter of getting used to technology:

> Some property owners, albeit few in number, are protesting against that which will make the district richer, through the increase in property values and the influx of travellers who will be conveyed there. […] What is it that we fear? Smoke? But it is a fact that coke, which is used to heat the locomotives, does not produce smoke. Noise? But it is generally agreed that a locomotive running on a track makes not half as much noise as a carriage running on cobbles [...] Now that the experience of our neighbours has refuted all these objections, there is probably nothing that will prevent us from implementing what is in the interests of the area, of the whole of Paris, and of the owners themselves." ("De la machine à vapeur locomotive. Premier chemin de fer de Paris", Le Magasin pittoresque, January 1836).

This was far from an isolated episode. The newspapers reported opposition from some members of the public, and even local authorities, in a number of cities. In Tours and Orléans, it was decided to keep the railway and its nuisance at some distance from the centre, which could explain the location of stations such as Les Aubrais and the subsequent construction of terminus stations in the town centre (Merlin, 1991). While the anecdotal nature of some of the sources suggests the need for caution, it is a fact that the issue of rail-related nuisance was a subject of debate in a number of cases. We will give two examples. In 1840, the rapporteurs on the preliminary project for the Orléans to Nantes railway expressed the problem in terms that, in more ways than one, evoke the world of the factory, to justify rejecting the building of a station inside the city: "Railways in general should remain outside cities, because in the interior they would be unpleasant, unhealthy and very damaging establishments, either because of the noise and smoke from the machines, or because of their shops, or because of the barriers that surround them [...]." (Lambert, 1992).

Similarly, in 1842, when the route of the future line from Paris to Lyon was being debated, Marie-Denis Larabit, parliamentary deputy for Yonne, argued against a direct service to the city of Dijon on the grounds that "it is in fact not in the interests of a city that people should travel through it, because all that remains of these convoys, so to speak, is smoke" (Le Moniteur universel, 26 May 1842). Subsequently, the issue was also debated in terms of the coexistence between industrial activity and pre-existing entities. In 1846, a collective petition was signed by more than 1300 Dijon residents against the creation of an embarkation point to the south-west of the town, in the immediate vicinity of the botanical gardens and the "asylum for the insane", the future general hospital (Archives départementales de

la Côte-d'Or, VI S1 A39). One of the reasons given for the petition was incompatibility: the very nature of these two institutions was such that they could not tolerate the presence of a noisy, smoky neighbour, especially as the latter was expected to develop its activities over the long term, in other words to expand its physical footprint and its influence.

This petition indicates that people expected the negative effects of the railway to become more intense in the future. The engineer Médéric-Clément Léchalas made similar comments in 1845 about the construction of Orléans station in Nantes:

> "We believe that locating the station at Prairie de Mauves would be a fairly good solution for a few years [...]. But we think that the inconveniences occasioned [...] by traffic on the rails would increase daily, so that the state of affairs would become intolerable in the not too distant future." (Lambert, 1992)

Figure 2 - Dijon station and its amenities around 1870

In addition to more material issues such as creating splits in the urban fabric, transforming entire neighbourhoods and damaging economic activities, concerns were also expressed about local impacts when the first stations were built, which is understandable given their industrial nature.

Initially, cities and railway stations appears to have coexisted without the fumes from locomotives being much of a problem. There were no significant complaints from neighbours in the early years of the rail industry (Émile, 2021), although descriptions of smoky embarkation points coated with coal dust suggest unpleasant and unhealthy conditions in the whole area between station and trains (Sauget, 2009). In other words, the dirt seems to have remained relatively contained within the railway space.

Following the British example, the authorities were careful to ensure that the rail companies burned coke in their engines, for the comfort of both passengers and local residents (Le Moniteur universel, 14 May 1845). Once distilled and freed of some of its gases, coal burns with less smoke. Air pollution was thus concentrated in coke ovens, which were often located on the outskirts of towns to produce gas for lighting (Thorsheim, 2002). During this period, which coincided with the establishment of the first stations in France, the companies adhered to this requirement in their specifications.

Price pressure, however, prompted the railway companies to consider the use of raw coal from the mid-1850s. General demand from industry and domestic consumption was growing faster than domestic production capacity, and imported coal was also becoming increasingly expensive despite the reduction or abolition of taxes. Coke, which was very much in demand in the steel industry, was becoming difficult to obtain. The Compagnie des chemins de fer du Nord, interested in the presence of compatible coal in the direct vicinity of its lines, initiated a rapid process of substitution that resulted in all the companies, with a few technical adjustments, switching to coal to fuel their freight trains, in the form of large pieces or briquettes (agglomerates generally containing tar pitch as a binder). This first phase of replacement ended around 1860 (Archives Nationales, 19800423/2 to 19800423/5). During this period, relations between the city and the railway began to become strained.

The replacement of coke with coal provoked an immediate reaction from neighbours affected by the smoke, which was more abundant, smellier (because it contained more gas) and dirtier, to the point that, in the mid-1860s, the engineer Auguste Perdonnet – despite being a great advocate of the railway cause – pointed out that the building of railways tended to reduce property values in nearby areas, whereas it was supposed to have the opposite effect (Sauget, 2009). In 1858, around thirty residents of the Mulhouse station district appealed to the authorities, particularly over the damage caused by coal smoke, which penetrated and caused damage “all the way into the houses” (Archives départementales du Haut-Rhin, 5S17). At the same time, a number of local property owners complained about the fall

in property values caused by coal smoke emitted from the engine sheds built near the stations. In Nancy, a straw hat manufacturer, like other craftsmen – in the ribbon or laundry industries for example – found it impossible to pursue a business that required periods of outdoor work (SNCF archives, 1890LM0011/007).

Aware of these industrial encroachments, the administrative authorities called for the exploration of substitute options that quickly extended to passenger trains. Here, the state was as much interested in the financial health of the railways and their ability to maintain operations as in the possibility of reducing dependency on foreign coal at a time when the Nord-Pas-de-Calais coalfield, boosted by rising demand, was sharply increasing production (Woronoff, 1994).

By 1870, coke accounted for only a tiny proportion of railway fuel consumption, although it had not disappeared altogether. In return for this latitude in compliance with the specifications, and because of the "numerous complaints" received from passengers and local residents, the authorities required the companies to fit locomotives with "smoke-absorbing" equipment that would "consume" the smoke in the engine fireboxes, in other words burning coal more efficiently (Archives Nationales, 19800423/2 to 19800423/5). This policy, introduced by successive circulars from the early 1860s, was finally extended to all industrial activities in 1865. In the case of locomotives, as for other engines, it did not produce the hoped-for results. And while railway workshops were included in the legislation on dangerous, unhealthy and polluting facilities, in 1866, this did not apply to stations and depots, the latter being the main source of air pollution from the railways.

In a relatively short space of time – around fifteen years nationwide, and sometimes almost overnight in the case of some towns – as coke was replaced by coal, smoke from steam locomotives acquired the status of a local problem. This dynamic, which continued with the use of increasingly cheaper and lower quality fuels, coincided with growth and intensification in traffic as well as increasing urbanisation and densification around infrastructures that were themselves proliferating or expanding to accommodate ever more passengers, goods and trains. As a result of this codevelopment, increasing numbers of people were exposed to ever-growing levels of pollution in and around railway facilities. By the end of the nineteenth century, the main stations and the neighbourhoods around them were acquiring a very negative image, with the daily press increasingly reporting readers' complaints and local conflicts. These complaints became all the more intense and visible as technical and fuel solutions began to emerge.

Tension in the air: the rail industry challenged for its smoke pollutionlution atmosphérique

During a period corresponding more or less to the "Belle Époque", approximately between 1870 and 1914, the passenger station came more and more to resemble a place that was "half-palace, half-factory". This ambivalence even found expression in fin de siècle literature (Baroli, 1964; Boeglin, 2018). The railway was as much celebrated for its benefits and for its aesthetic qualities as it was decried for its noxious impact and the ugliness of the industrial world it embodied. In large cities, the press reported numerous conflicts between the industry and its neighbours.

From the end of the nineteenth century onwards, main passenger stations were increasingly perceived and described as unhealthy places, as Pasteur's germ theory of disease gained ground along with growing awareness of industrial pollution (Baret-Bourgoin, 2005). If the station was a palace, according to the architect Augustin Rey, it was first and foremost a "palace of smoke" with soot-covered canopies that struggled to rid themselves of locomotive fumes (La Technique sanitaire et municipale, April 1913). The gloom and filth of railway stations is a recurring theme in the press and literature of the time. For certain journalists, it was a "cavern of stale air, crowded and polluted platforms, dull and dirty walls, tarnished and soiled windows, illegible clocks and tattered posters." (La Lanterne, 9 September 1924). To mitigate the revulsion of passengers, some timid greening initiatives were introduced, but they proved somewhat futile by comparison with the blast of powerful machines:

> "When the locomotive stands still at the end of its platform, the smoke rises straight up into the air and soon falls back to the ground, impartially coating everything in its vicinity, from the shop assistant's newspapers [...] to the station master's beautiful white cap." (Paris-Soir, 21 July 1927). For that reason, passengers were advised not to wear clothes that too easily showed the dirt.

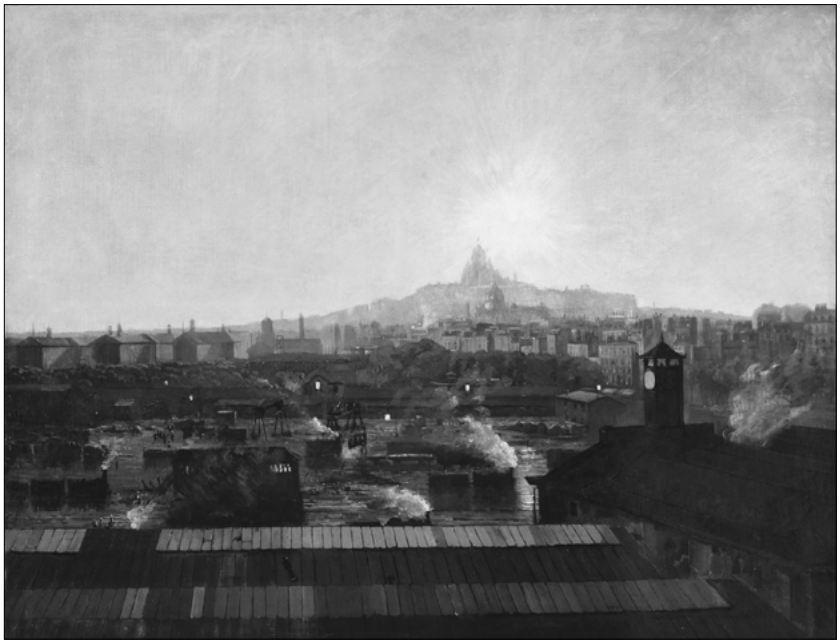
Despite efforts to ventilate them, which rarely included artificial ventilation systems, stations remained smoky places blackened by coal dust and soot, in addition to the noise and general dirt associated with the concentration of mechanical and human traffic. Opened in every direction, stations spilled over into the surrounding neighbourhoods. The railway companies, which could not use tall chimneys to evacuate smoke, tried to reduce it through various "smoke-consuming" processes, and above all by shifting the responsibility to the train drivers by means of supervision and penalties. This did not protect the neighbours from the smoke: when it came to a choice between passengers and local residents, the companies prioritised the comfort of the former, especially as they tended to buy up the housing blocks nearest the stations (Nilsen, 2008; Sauget, 2018).

3. Jean-Joseph Enders, *At la gare Saint-Lazare station, oil on board*, 1912

Living near a station in the steam age meant being exposed to a whole host of noxious effects. Most of the complaints were about vibration, the noise of the machinery and the whistle, and the smelly coal smoke, which settled as soot on the facades and windows of homes, even filtering inside. Like people living near factories, the station's neighbours had to keep their windows closed, although this was not enough to protect them. The smoke from the stations was even blamed for contributing to the smog that came to envelop the entire capital.

> "Paris [...] has its smoke as London has its fog. [...] The locomotives at all the stations belch out a thick smoke mixed with solid matter which, when added to the smoke from the factories – themselves growing ever more numerous each year – produces this curtain of haze from which we suffer particularly on hot, airless days" (Le Gaulois, 12 August 1911).

> "It was foggy over the city, and I was about to cross the Pont de l'Europe when I had to stop to find my way, so dark was it in this part of Paris. All the locomotives built by Vulcain for Saint-Lazare station were belching out thick smoke, and this artificial haze, mixed with the natural haze, produced a nauseating amalgam that poisoned the busy neighbourhood. This constant haze made me regret that, in the twentieth century, civilised people had not yet found a way of eliminating from their daily lives the thick billows of smoke that blacken facades, anger residents and blow the dust commonly known as soot into your eyes" (Guy Launay, "Volutes", Le Matin, 14 January 1925).



4. Louis-Robert Carrier-Belleuse, *Les Voies de la gare du Nord, les toits de l'hôpital Lariboisière et la colline de Montmartre*, oil on board, ca 1895

Since the 1870s and 1880s, the number of stations in the city had increased in step with the development of local trains and mechanical trams, some of which were initially pulled by steam engines (Caron, 1997). The main stations themselves had expanded, and the city had caught up with them to such an extent that the districts around them were no longer peripheral but had become central. Industry had come to exert a major influence in certain localities. In a city like Paris, hemmed in by the beltway train line and criss-crossed by multiple lines leading to passenger or goods stations, themselves with engine sheds for locomotives, there is no doubt that the railways were one of the main sources of air pollution. Beyond this general condition, some areas appeared to be more affected by the problem than others: in Paris, the districts of Goutte d'Or, La Chapelle, Batignolles, Bel-Air, Quinze-Vingts, Santé and Charonne regularly aired grievances linked to the proximity of rail infrastructure. The façade of Hôpital Dubois (now Hôpital Fernand Widal), a distinguished nursing home unfortunate enough to have been built between the Gare du Nord and the Gare de l'Est, presented a less attractive appearance to visiting celebrities every year (Le Radical, 19 September 1923). Lariboisière hospital was not much better off. Sandwiched between various stations, certain central districts were also among the victims. This was true of the ninth arrondissement, where the wind rarely heralded good news.

In Bordeaux, reports from the Midi (Bordeaux Saint-Jean) and Orléans (Bordeaux Bastide) stations expressed similar criticisms (Gazette hebdomadaire des sciences médicales de Bordeaux, 3 April 1932).

Outside the neighbourhoods immediately around the main stations, the Ceinture, Vincennes and Sceaux lines were described as filling entire streets with smoke because of cuttings, viaducts and underground passages, all of which prevented the smoke dispersing effectively. In Nantes, the line to Saint-Nazaire, running along the banks of the Loire very close to residential buildings, was the target of articles reporting the frustration of local residents forced to live with their windows closed, particularly near Gare de la Bourse (Le Phare de la Loire, 27 September 1911). This type of complaint could be heard in most cities, but also in smaller towns, directed at major rail networks, local lines and steam tramlines alike.

Dirt was only one aspect of the problem: in the presence of humidity, the sulphur dioxide released by coal burning is converted into sulphuric acid. Because of the combustion of bituminous coal, locomotive smoke was reputed to be particularly corrosive, reproducing at its own scale the kind of acid rain that eats away at industrial cities (Brimblecombe, 1987). By the end of the 1890s, engineers noticed structural problems with the network's metal components, particularly footbridges over the tracks (L'Union libérale, 16 March 1893). This finding prompted them to make greater use of concrete. Around 1930, the new steel frame of the Pont de l'Europe was encased in a layer of cement to protect it from engine fumes, in sharp contrast with the poetic billowing clouds depicted in Impressionist paintings (Excelsior, 7 December 1928). Inside and around railway property, the smoke from the trains ate away at masonry and metal, infrastructure and monuments. As journalist Arthur Lafon noted, "nothing could resist the smoke from the locomotives" (Paris-Soir, 28 February 1928).

Despite these problems, official complaints remained rare, no doubt because legal precedent was not particularly favourable to neighbours. Those complaints that did reach the authorities generally came from owners with a certain amount of social and financial capital. Tenants and sub-tenants, on the other hand, were largely powerless, and it was journalists and local councillors who generally spoke out on their behalf, for example by calling for a return to coke or the fitting of smoke containment equipment, which continued to generate as many promises as patents despite the evidence of its ineffectiveness. The tensions revealed by a study of the press are all the more palpable as alternative methods of pulling carriages had been accumulating since the 1870s and 1880s: soda, gas, compressed air, on-board steam containers (fireless locomotives), petroleum, coke by-products, electricity, etc., all of which produce less smoke than coal, if any at all. These alternatives, which were sometimes seen as miracle solutions, nevertheless created other problems. As with

coke, air pollution could concentrate around power generation plants. In 1907, Compagnie du Paris-Orléans was fined for the smoke emitted by its factory near Tolbiac Bridge in Paris, which supplied electricity to Orsay railway station (Bulletin des arrêts de la Cour de cassation rendus en matière criminelle, 6 February 1909).

Electricity was a key player in this context. In terms of railway applications, its development quickly captured the attention of the press from the 1880s onwards. Apart from trams, the first urban rail applications of electricity were introduced against the background of the 1900 Universal Exhibition in Paris, especially on underground sections. Following the example set in London, electrification began on the section of the metro from Austerlitz to the Quai d'Orsay, which housed the first electric train station. The electrification process was very gradual and for a long time was restricted to (sub)urban, underground and mountain lines, for economical and safety reasons mostly (Bouneau 1997). Moreover, stations were often electrified before trains, for heating and lighting. Small electricity production plants – which emitted their own fumes – were constructed close by.

Demands for the electrification of railway lines emerged at a time when the railway's role in urban air pollution was gradually being recognised, in the context of intensified efforts to combat industrial fumes, which had ceased to be a purely local nuisance to become a public problem. The complaints were backed by the growing number of scientific studies on air quality, particularly those carried out by Dr Frédéric Bordas (1860-1936) in Paris (La Technique sanitaire et municipale, November 1928). As well as affecting human health, the smoke damaged nearby buildings and vegetation. Electrification of the lines thus became a matter of "health, hygiene and aesthetics" (L'Homme libre, 23 April 1924), and even of urban planning. In any case, it was a political issue, regularly raised in speeches and debates on county and municipal councils, and even in the Chamber of Deputies, led by elected representatives from the towns and districts most affected by the problem.

In Paris, an early call for full rail electrification was issued in 1897 by the socialist Victor Dejeante, on the grounds that it was "a question of health and hygiene, which need to be protected" and that people who were already being poisoned by the sewers should not be "poisoned by train smoke" (Le Petit Temps, 26 October 1897). After unsuccessful negotiations on the type of fuel or pollution control systems to be used on locomotives, the issue of electrification began to be debated more seriously by the city council, particularly in 1912 and 1930 (Archives de Paris, AP D1S9 1; Le Matin, 9 July 1930). These repeated demands reflect the impatience expressed by local residents in response to a situation that had become all the more unbearable as its resolution seemed within reach.

> "Stations, the big stations of the tentacular cities, will remain supremely gloomy. One of the elements of this gloom, no less literary and most directly perceptible, is the heavy smoke that stinks out the atmosphere in the halls, dulling the glass of the windows and the light of the existing displays, but above all staining the walls with that funereal greyness in which the most cheerful soul cannot help but feel that to part is indeed to die a little... [...] But stations are not impenetrable enclosures. Their gloom emanates from them, along with its source, the smoke they spread. Have you noticed that all the windows around the stations are closed, as if for the passing of a convoy? It is a precaution and a means of defence. But smoke knows how to find its way in. [...] Local people [...] are asking their local councillors to intervene to "prevent the spread of these toxic and highly noxious fumes!" [...] Thy kingdom come, integral, divine Electricity..." (Alexis Danan, "Smoke in Paris. Les riverains des gares et de la Seine se plainent de vivre dans une atmosphère empoisonnée", Paris-soir, 10 February 1928).

While electricity was the solution favoured by local residents, the press and the authorities, its full implementation was considered too costly and even a threat to national security in the event of conflict, more easily exposing the rail network to the risk of sabotage. The Morizet Act of 1932, which aimed to eliminate atmospheric pollution, proposed partial electrification. This would involve a change of traction systems on the outskirts of cities, as was already the case at Austerlitz, as well as improvements in the machine heating processes in the engine sheds (Archives de la Préfecture de Police de Paris, DB 434). Coke fuel was restored on certain urban lines and for some shunting locomotives, while promises of smoke-consumers with miraculous properties resurfaced. But it was the gradual diesel-electrification of the lines, or even the elimination of some, which eradicated (or transformed) this major source of pollution.

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In the steam age, mainline stations could fairly be described as "transport factories", producing noxious emissions similar to those of certain industrial plants, notably the coal smoke that spilled into the city in the absence of any means of containing it within railway premises. As open industrial spaces containing mobile production units, they revealed the incompatibility between operating requirements (including passenger comfort) and the challenges of coexistence with neighbours. With the ongoing changes in energy sources and the co-development of the city and the railway, its eradication became a city-wide issue of "health, hygiene and aesthetics". From being a local issue confined to station areas it had come to be perceived as part of a public problem.

Beyond the heritage and tourist lines using steam locomotives, train smoke continues to survive in many forms, from road signs to artistic production and design, via the pictograms in our digital tools, mediating an imagery

of the railway which, paradoxically, retains no memory of the problems associated with it. In fact, as steam engines become a thing of the past, and passenger buildings acquire heritage status, the tendency is for this pollution to be forgotten, replaced by an aestheticised and sanitised image of the historical object. On the one hand, a process of de-romanticisation is confronted with the power of the social imagination and with the position occupied by the steam locomotive in Western culture for all that it represents: the 'religion of progress', a triumphant modernity, a fantasised golden age. And on the other hand, it is confronted to the absence of obvious traces to interpret.

However, it is possible to identify some residual elements or traces that point to a problem that continues to be present, in new forms or by a lingering effect, in the urban environment. For example, the dwellings on either side of railway cuttings are generally set back some distance from the track, or present blind walls. Also, in historic stations, the size of the train sheds and the presence of skylights are evidence of the past significance of smoke in station operations, as are the draughts that passengers experience (Ben Hadj Salem, 2009). The same is true for the historical materials. As part of a heritage-based approach of train stations, it is important to understand the reasons for each material presence and layout, which arise from a combination of the spread of certain technologies and imperatives linked to the costs of building and maintaining infrastructure. As far as the train sheds and historic platform shelters are concerned, these materials have always been designed with durability in mind, particularly with respect to exposure to smoke.

The formation of Japan's post-carbon railway landscape and the gamble on natural resources

Corinne Tiry-Ono

When stations are considered in terms of their relations with their local or more distant environments, their impact is most often viewed in terms of the passenger flows they collect or distribute, as network points with variable effects (polarisation, fragmentation, etc.), some of which leave a significant mark on the landscape.

However, different territorial changes take place once other types of flow – less visible but essential to the operation of rail systems – also become subject to observation. As in other domains, the energy supply to the rail industry – in the broadest sense – is responsible for integrated or parallel infrastructures and facilities that depend on the nature of this energy. Originally visible in the form of coal, whether in the activity of coalmines or the architectural morphology of train sheds[1], energy flows in subsequent periods have shaped other more or less identifiable forms and landscapes. In the case of electricity, for example, because the energy flows are nonmaterial, a type of station design that mimicked the stand-alone air-conditioned box shape of the shopping mall appeared during the second half of the twentieth century, separating stations from their environment, while generic energy landscapes (e.g. pylons carrying high-voltage lines) developed without territorial anchors (Lopez 2022).

In other words, the direct or indirect relations between the type of energy used and the material and landscape forms generated by rail mobility govern the spatial interactions between the different systems in question: energy, territory, landscape and architecture.

In view of global environmental concerns, which have prompted questions about the nature – and particularly the depletion, environmental impacts and costs – of the energy sources used, and despite the fact that the

1. On the history of the architectural typologies of railway stations, see the seminal work by Carroll Meeks (1956); on the history of the railway industry in France, see the writings of François Caron (1997, 2005 and 2017).

rail sector is a low CO2 emitter compared with other mass transport modes, its practices are not exempt from reappraisal. With the gradual introduction of renewable energy to power railway infrastructure and facilities, are other forms of spatial interaction emerging, and if so on what scale? How are the objectives of energy frugality and autonomy, reliant in particular on the use of natural resources, redefining these interdependencies between rail transport and local territories?

In an entirely different context, the observation that "ecology brings to light new relations of interdependence that can form the basis of new connections between rootedness and mobility" (Mormont, 1996, 58), raises questions – in the field that interests us here, the railway – on the one hand about the nature of these new connections, and on the other hand about the architectural and landscape forms that they produce.

Being part of the landscape themselves, the natural resources exploited by the railways for ecological ends could thus become more visible. Conversely, the urban or rural landscapes altered by the exploitation of these resources could make the interdependencies between the various major systems involved more visible and intelligible. In other words, we assume that growing dependence on natural resources, with the changes it brings about, would anchor mobility (its practices as well as its infrastructures) more at the local scale and would in turn contribute to a visible impact on the landscape.

Because it has emerged as a pioneering instance of this dual dynamic – on several scales – we have chosen to look at the methods adopted by the Japanese railway company East JR to incorporate natural resources into its energy mix and, beyond that, into its ecological strategy. With 1,677 stations and a network of almost 7,500 km of track carrying 13 million passengers a day[2], East JR is a private company that serves the east and north-east of Japan, including the Tokyo metropolitan region and the less built-up region of Tôhoku[3]. The exceptional conditions of the post-2011 period (following the earthquake, tsunami and Fukushima nuclear accident) made this region a national testing ground for new regional energy infrastructures drawing on the renewable resources available there[4]. Have stations been a part of this process? How does the enlistment of natural resources affect them and their relationship with their immediate environment, whether urban or rural.

2. East JR data at 1st April 2022: https://www.jreast.co.jp/e/data/

3. Privatisation of the national company Japan National Railways (JNR) in 1987, when it was divided into 6 regional passenger transport companies and a dedicated freight company.

4. "(...), Fukushima Prefecture decided to ban nuclear power generation in order to become a pioneering region in the development of clean energy. The target is to reach 40% renewable energy by 2020 and 100% by 2040" (Scoccimarro, 2022, online).

To sum up, the aim of this article is to describe the multiscalar changes arising from the implementation of new systems intended to renew East JR's station and infrastructure model with an eye to environmental priorities

The issue of energy and cutting CO2 emissions from rail activities: conversion and regionalisation

Faced with the demographic decline that Japan has been experiencing since the turn of the century, the rail passenger transport sector has entered an unprecedented phase of transition. Now entirely in the hands of the private sector, this powerful economic instrument was forged and shaped throughout the twentieth century in support of Japan's growth paradigm. From the 1990s onwards, weakened by national conditions of economic stagnation and decline at various levels, Japanese railway companies had to rethink their business model from a new strategic perspective.

The closure of many small lines in declining areas, and the fall in ridership rates on major metropolitan facilities, signalled the end of a well-established model based on the absorption and management of exponentially growing passenger flows. Maintaining the attractiveness of stations solely by offering a large range of shops and services was no longer enough to offset the decline in passenger numbers[5]. Some realised that environmental responses, in all their multiple dimensions, offer an opportunity to revise the historical growth-based model and replace it with a service offering that takes account of the archipelago's specific societal challenges as well as the planetary problem of climate change.

The aim of the strategy adopted by the East JR company over the last thirty years or so, and of changes to that strategy[6], has been to implement a set of key programmes and systems which – at different scales – incorporate ecological priorities. More specifically, the energy used by the operator-developer in the design of stations – in the sense of the construction/conversion, maintenance and protection of stations – as well as in supplying energy to its infrastructures, has been reassessed to incorporate a growing proportion of natural resources (renewable energy, plant materials).

From the statistics and reports published by the company in this domain, we identified a trio of interventions that are significant in purpose and scale, which have been under consideration or implemented since the mid-1990s.

5. Which varies from one place to another.

6. The objective is to achieve a 40% reduction in greenhouse gas emissions by 2030 compared with 2013. The Japanese government's target is 46% for the country as a whole and carbon neutrality by 2050 (data from the Japanese Ministry of the Environment: https://www.env.go.jp/content/900442543.pdf).

In March 1996, four years after the Rio Conference[7], East JR published its first environmental action roadmap (Okuno, 1998, 14). It gave priority to tackling the electricity used to run the trains, which accounted for 80% of all the energy consumed by the company and was the main source of CO2 emissions. Partially self-sufficient in the production of its own electricity, at the time it had a fleet of four power stations which supplied just over half its electricity needs[8]. Its three hydroelectric power stations on the Shinano river[9] and its thermal power plant in the industrial region of Kawasaki, south of the capital, were progressively modernised. At the same time, its rolling stock fleet was replaced by lighter models that consumed less electricity. The target was modest, to reduce CO2 emissions by 10% by 2001.

Other measures, such as reactivating the century-old railway forests – a subject that will be developed in the third part of this article – or reducing and recycling the waste produced in stations[10], constituted the other planks of the strategy. The focus on improvements to macro-infrastructure and rolling stock, the company's traditional areas of expertise, was understandable just ten years after privatisation.

A decade later, the roadmap had become more ambitious, aiming to tackle the various sources of CO2 emissions from rail activity in a more systemic and multi-scalar way. With the publication of its "JR East 2020 Vision - Challenge" in March 2008, the company announced a target of halving CO2 emissions from rail operations by 2030 compared with 1990 levels. In both 2006 and 2007, these CO2 emissions totalled 2.12 million tonnes (Inoue, 2009, 22). This "vision" now included stations as a target for CO2 emission reduction measures – a subject we will develop in the second part of the article. With the Urban Renaissance policy launched by the state in 2001, these network nodes and their mixed neighbourhoods were designated as strategic locations for urban renewal and pivotal points for the development of a compact city model advocated by the national and metropolitan authorities.

Efforts to cut CO2 emissions from the company's thermal power stations were refined as the ratio of renewable energy in the mix increased:

7. United Nations Conference on Environment and Development, or Earth Summit, June 1992.

8. East JR generates its own electricity (from its own power stations) for powering its trains, its stations and offices, and the air conditioning in its buildings; it also uses diesel and paraffin to run certain locomotives and to heat its stations, offices and other facilities.

9. The archipelago's longest and widest river, which rises in the north of the island of Honshû (a territory served by East JR), is dotted with dams and power stations, most of them built by the government after the Second World War.

10. The 17 million daily passengers on the East JR network produced 80,000 tonnes of waste a year (1% of the waste collected in Tokyo) (Okuno, 1998, 15).

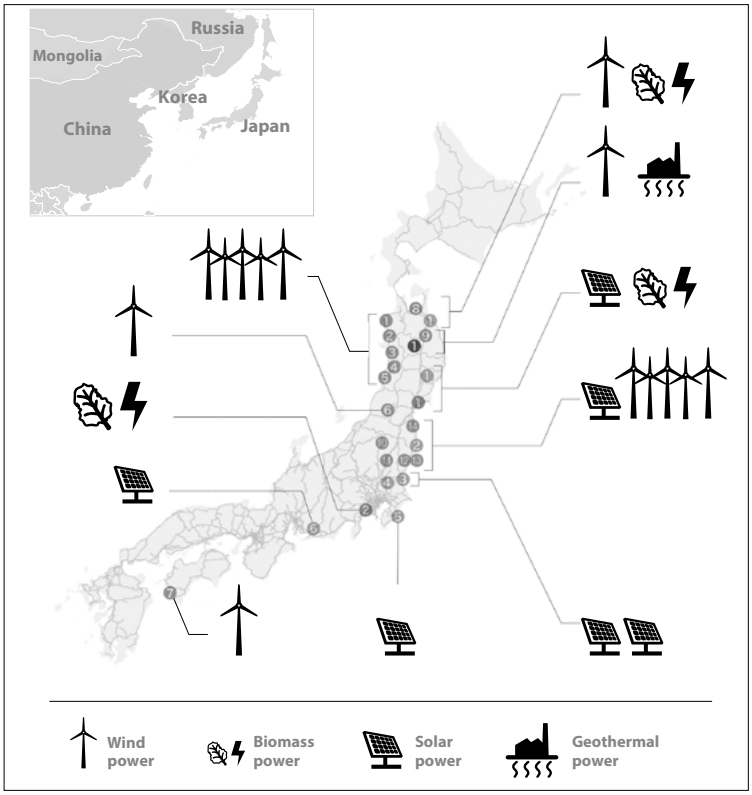
measures to use solar and wind power were gradually introduced, though they remained a small part of the total energy mix. However, the government's recognition of the phenomenon of "superdepopulation"[11] in rural areas of Tôhoku, and the Fukushima nuclear disaster and accident in 2011, accelerated this process of diversification. The national policy of developing renewable energy in this particularly vulnerable region made it a laboratory for experiments on the production of clean energy through the use of natural resources (wind, solar, volcanic hot springs). With relatively low urban development, the region – particularly in rural and coastal zones – had huge areas available for new energy production and distribution facilities and infrastructure.

Another decade on, around 2017-2019, these new infrastructures were operational. All are located in the Tôhoku region. Two wind power plants had been commissioned at the tip of Honshû's north-west coast (Minehama, Mitane), along with a biomass plant in the north-east (Hachinohe), and studies were underway on a geothermal plant in the hills north-west of the town of Morioka (Omatsukurayama). Finally, in the southern part of the east coast, a massive solar farm had been set up at Tomioka (near Yonomori station on the Jôban line, in the immediate vicinity of a photovoltaic panel factory) (Figure 1). At the scale of the area served by East JR, the extra-peripheral concentration of these power stations created a new technical hub, on the coast, dedicated to the railways. By employing locally available natural resources, it paradoxically contributed to a radical transformation of the region's historical farming landscape[12].

The principles of the Eco Station: redevelopment from the generic to the specific

The "JR East 2020 Vision - Challenge" (2008) also included a plan to adapt stations to the climate challenges, with a view to cutting their power consumption and associated CO2 emissions. In big stations, the highest source of consumption was air conditioning (Inoue, 2009, 23). It was during major architectural renovations to these ageing facilities that the technical systems for treating the air inside them were reviewed, particularly in the web of

11. "In 2016, 46.4% of Japanese municipalities were classified as superdepopulated, i.e. in the throes of severe demographic decline." (Scoccimarro, 2018, 28).
12. This is part of a much wider territorial and landscape transformation: wind turbines have been erected along the coast and solar farms have in some places replaced the region's farming activity, which is difficult to maintain for a variety of reasons (contaminated soil near Fukushima, but also an ageing population, demographic decline, etc.). See the map of the many solar farms developed in Fukushima Prefecture, produced by Mitate Lab (CNRS) in April 2023: https://mitatelab.cnrs.fr/actualite/mitate-labs-map-with-photovoltaique-and-contaminated-wasted-land/



1. Stations associated with a series of energy production processes

Source : East Japan Railway data, mapping by N. Le Bot, no further use allowed).

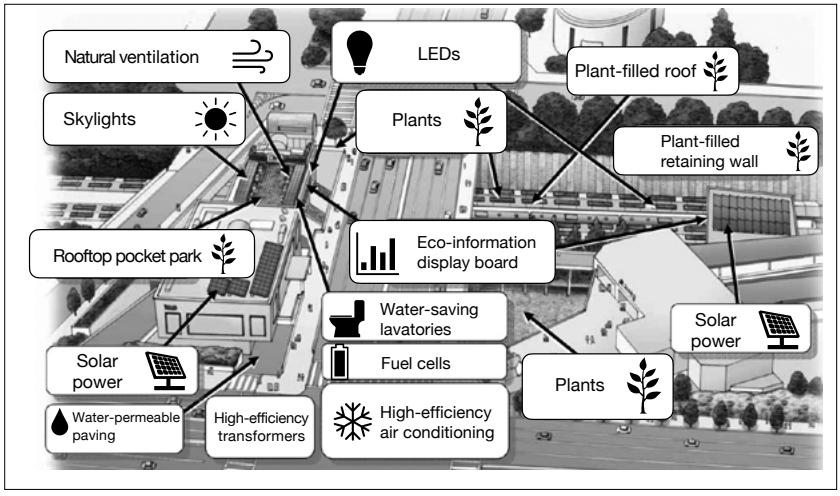
underground spaces that were widely developed in the 1960s-1970s, mainly in Tokyo, to absorb the exponential growth in passenger flows and develop retail activity[13]. Other major stations with long outside platforms gradually installed photovoltaic panels on the platform roofs to supply part of their electricity needs. The installation of green roofs on the company's passenger and commercial buildings was also intended to reduce heat island effects and hence cut the need for air conditioning. However, these improvements were dependent on the morphology of the buildings and the configuration of the railway infrastructure.

More systematically, the so-called Ecoste programme (derived from 'eco-station'), launched in 2008, focused on a series of pilot stations that were to act as 'models' for user communities through the implementation of various pro-environment technologies and systems (Figure 2). Suited to a standard station configuration, usually a small-scale facility (40% of the fleet), these adaptations were designed to achieve more than the economic

13. In the capital, this is the case at Tokyo and Ueno stations in particular.

goal of reducing the facility's electricity consumption. The aim was to rethink the entire complex (passenger building and infrastructure) as a unit that is both self-sufficient and linked to the immediate urban or rural environment, both for the natural resources that the latter can provide and the services that the station can offer beyond its primary function as a transport facility or point on a network[14]. Three main types of adaptation encapsulate this approach, based on a form of reciprocity marked by a mix of autonomy and interdependence:

– using monitoring systems to reduce the amount of electricity and water consumed in the station, creating openings in the facade or roof to admit air and light naturally, and replacing lighting and information equipment (LEDs) and ventilation equipment (mechanical fans);
– producing energy directly on railway buildings using natural resources (solar radiation, mainly photovoltaic panels on the roof, and according to location: wind, natural hot water);
– reducing temperatures in urban environments by planting vegetation on track retaining walls and platform roofs, or even creating accessible pocket parks on roofs or in residual spaces created by the infrastructure, and laying water-permeable paving on forecourts[15].

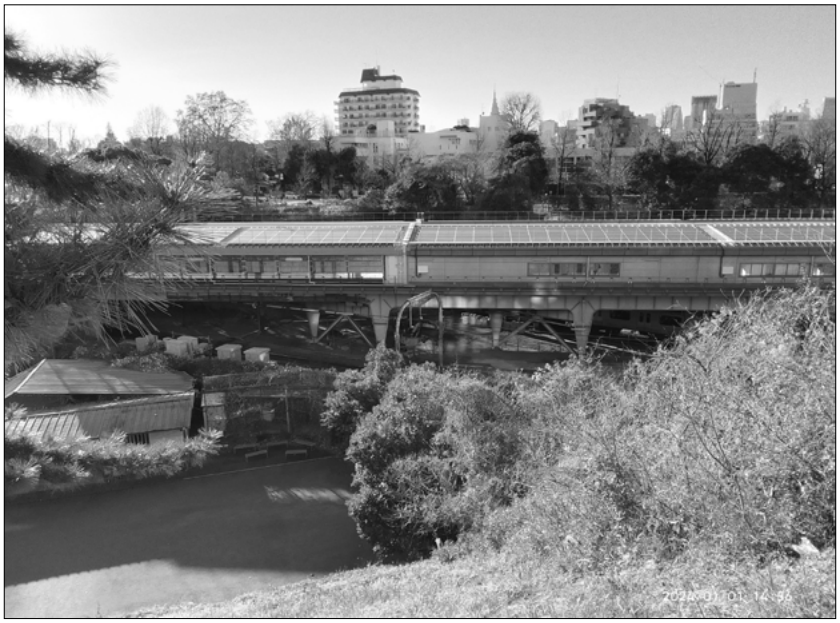


2. Ecological and energy functions associated with Yotsuya station

Source : East Japan Railway data, cartography by N. Le Bot, no further use allowed)

14. The Ecoste programme also includes other more common sustainable mobility measures (intermodality, park-and-ride system, better facilities for active travel modes at stations, etc.), which we will not go into here because we prefer to concentrate on the topic of natural resources.
15. It should be noted that in the case of Tokyo metropolitan region, these railway lines (tracks, embankments, etc.) are a part of the Environmental Axis Plan (kankyô jiku) in the same way as other planted traffic routes.

The first pilot station, Yotsuya, located in Tokyo's hypercentre, was upgraded in 2011, and an initial review was carried out in 2013. Located close to the Imperial Palace, on the Chûô overhead line that crosses the metropolis from east to west, and at the junction with a metro line, Yotsuya station handles 170,000 passengers per day on the East JR line and around 100,000 more via the connection with the underground railway. This bridge station was selected because of the potential offered by its structure and topographical environment: the deep-set tracks are bordered by high, rough retaining walls that are ideal for planting, while the long outside platforms can be covered with strips of lawn[16]. Topped with glass roofs covered in translucent solar panels, the flat roof of the now plant-filled passenger building forms the heart of the facility's natural ventilation system. Its CO2 emissions were estimated in the review at 40% less of their 2008 levels, and the temperature readings show a reduction in all traffic zones and the disappearance of the highest heat gradient (Okada 2013). However, further south, the roofs of the elevated metro platforms were able to receive solar panel equipment (Figure 3).



3. Continuous photovoltaic roofs over the platforms at Yotsuya station

Photo : C. Tiry-Ono.

16. On the other hand, the proximity of the Imperial Palace and its historic protective perimeter precluded the installation of photovoltaic panels above the platforms, which would have been visible from the Palace.

A further nine Ecoste pilot stations across Tôhoku were scheduled for completion in 2020. Their adaptation or reconstruction drew directly on local natural resources. For example, the Oga terminus station on the coast of Akita prefecture, rebuilt in 2012, is now entirely powered by a series of wind turbines erected along the track; at Yumoto station, located along the river of the same name to the south of the city of Iwaki, electricity needs – particularly to heat the interior spaces – are partly met by harnessing local geothermal resources tapped when the passenger building was rebuilt in 2014. In both cases, the emphasis on the use of both natural and cultural 'assets' serves to enhance the area and the sites' tourist appeal, while at the same time boosting the appeal of these small stations, some of which are under threat.

Reassessment of railway forests: restoring a historical resource

Another natural resource that forms part of the array of post-carbon programmes and systems developed by East JR is forest trees, a capital asset that is currently being reappraised. At the end of the last century, the company owned 4,400 hectares of forest along its tracks, with around eight million trees, corresponding to 25% of all the land in its possession. In 1992, to preserve these precious green belts, East JR initiated a participatory programme in cooperation with local residents to green more lines by planting 30,000 trees each year (Okuno, 1998, 15). In 2015, the reforested area more than doubled to 10,000 hectares (Shimamura, 2015, 249).

Apart from this campaign, the railway company's strategies for the use of its forestry capital entailed reviving a historical practice linked with climate risks, particularly in the Tôhoku region. More often than not, at least in Japan and Europe, the connection between the forestry and railway industries has generally been limited to the exploitation of timber, timber transport for commercial purposes, protecting infrastructures from the risk of falling trees or, more recently, regenerating disused urban railway land by rewilding. It is much rarer for timber to be treated as a resource that contributes to the regional ecosystem of a passenger transport network.

Etymologically, two different expressions describe these two complementary but distinct activities in Japan. The first expression: 森林道 (*shinrin tetsudô*)[17], or "forest railways", refers to a previous but now declining economic system. The second: 鉄道林 (*tetsudôrin*),), or "railway forests"

17. 林 = hayashi = wood, bunch of trees; 森 = mori = wood, forest; 森林 = shinrin = forest. The (single) English expression Forest railway covers only the first meaning.

(Figure 4), refers to an activity that encompasses network maintenance, the prevention of natural hazards and, more recently, the capture of CO2[18]. Geographer Philippe Pelletier describes Japanese forestry as "paradoxical". Although 66% of the country is covered in forests, Japan "has become the leading importer of wood, accounting for a quarter of the world total. (...) because imported wood is cheaper" (Pelletier, 2008, 21). Both domestic output and imports of this resource fell during the economic boom of the so-called High Growth period (1955-1973), with local consumption collapsing from the early 1970s. Over the same period, the three categories of forests in use – municipal, state-owned and private - also saw their surface areas shrink under the pressure of urbanisation and industrialisation, as well as through the priority given to concrete and steel in the construction sector[19].

In the archipelago, the very first snow-break forest was planted in 1893 near Noheji station on the Tôhoku main line to protect train traffic from blizzards. Up until the 1960s, forests and woodlands along railway lines were widely used to protect infrastructure from avalanches and landslips, to prevent soil erosion and to store water for steam locomotives. Rehabilitating and preserving these forests requires a shift from monoculture (mainly Japanese cedar) to a mix of native species, in order to ensure greater hardiness and longevity[20]. The collaboration between local populations and the authorities is part of a wider drive to revitalise declining areas and protect cultural assets. As a result, other practices are developing: leisure, nature and landscape conservation, adding further dimensions to the environmental value of the railway. A new form of interdependence is emerging between the technical transport network and local natural resources.

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Drawing upon the case of the East JR company, this article has sought to identify the programmes and systems that reflect the emergence of interdependencies between the railways and the land, at different degrees and scales, in anticipation of a post-carbon world.

Over the space of a generation, cutting CO2 emissions has become an important operational factor in the company's strategy to make its rail

18. This second category may also include the processing of timber resources, but this is not its main or original purpose.
19. Recently relaxed, fire regulations have been one of the major obstacles to the use of wood in construction in Japan since the Second World War.
20. *Atarashii tetsudôrin* 新しい鉄道林, or "new railway forest", an initiative started in 2007. See for example the press release for one of the campaigns, here in 2019, between Kado and Moritake stations (Online): https://www.jreast.co.jp/akita/press/pdf/20190910-1.pdf

4. A railway forest to prevent snowdrifts – Uetsu line (Honshû)

Source : Shimamura M. (2009). " Railway Protection Forests. Reducing Natural Hazards and Enhancing Environmental Values ", *Japan Railway & Transport Review*, n° 51, p. 19, no further use allowed)

business more attractive. Against the background of a decline in passenger transport in Japan since the beginning of the twenty-first century, and in an attempt to stem the shrinkage in revenue from transport alone, the historical parallel activities (mainly retail, services and real estate) of Japan's private railway companies have been supplemented by the energy sector. Their aim here is first and foremost to reduce energy costs and consumption, while developing a more eco-friendly model. In the specific case of East JR, this has led to the rollout of technical programmes and systems and the modification of equipment and infrastructure at all levels, using locally available and usually renewable natural resources. It has become an additional branch of activity undertaken for the purpose of balancing the budget while at the same time generating other forms of attractiveness.

The effort to cut energy costs by measures to reduce railway CO2 emissions entails reallocating these solutions geographically to match the location of the natural resources to be captured or reactivated. As a result, new regional centres are emerging across the network, transforming the railway landscapes inherited from the previous century. With respect to station architecture, emerging new typologies seek to open stations up to the outside world in a variety of ways, making them permeable to or interdependent with the immediate cultural and landscape environment. Revitalising certain declining areas or activities should also have the effect of consolidating the local roots of the network – both stations and power plants. Industrial repurposing and the re-evaluation of local potential are

also consistent with the historical role played by the railways in Japan since their beginnings, in terms of regional planning and the shaping of landscapes.

Stations and Heatwaves: Travel practices and railway resilience reshaped

Nacima Baron and Hala Zouad

How do the powers that be assess the challenges posed by heatwaves and seek solutions? In proposing an answer to this question, the survey presented in this chapter occupies a position at the intersection of two disciplinary fields.

On the one hand, rising temperatures in stations raise the question of what causes them, how to measure them and how to limit their harmful effects (Zimmerman et al., 2022). Rail transport requires equipment that consumes a lot of energy and produces heat. As a result, a station is a kind of heat island within the broader urban heat island. Certain physical components of the infrastructure will need to be adapted and, in the long term, the operation of rail services will have to be revised significantly.

On the other hand, in sociotechnical approaches to infrastructure systems and in climate anthropology (Kobi 2022, Knox 2020), practices are observed in order to better understand how the problem of heat arises and how it affects the ways of knowing and doing that are specific to station management. Research in these fields is based on the assumption (which we will endorse in this chapter) that climate conditions are beginning to undermine the technical performance of the rail system and even, more broadly, the wider legal and economic dimensions in which stations and railways operate as an industrial sector and a public service. Is a new climate regime for railways emerging as a result of global heating? We will attempt to clarify the term "regime" by measuring the difficulties, both practical and theoretical, that global heating presents for an industry that is very sensitive to matters of safety and resilience.

In combining these two approaches, this research thus asks a framing question: what technical and theoretical tools are employed to study, observe and understand heat in stations? Inspired by pragmatist sociology, our argument is that this constitutes a "litmus test" (Martuccelli, 2015). Heat is crashing into stations, understood as worlds governed by the dominant value of fluidity, an essential condition for the regular movement of trains and people. But is it just the weather that is disrupting

this well-oiled system? Are the analytical frameworks and the forms of decision taken by those responsible for overheating stations – today and even more tomorrow – shared and accepted by the public? The notion of a test suggests that we are undoubtedly living through an intermediate stage of recognising the reality and magnitude of the changes that will affect the nature and function of stations.

The approach we adopt is inductive. We begin by looking at the disorder caused by contingent weather conditions (part 1), and then consider the structural vulnerabilities of infrastructures to the heating that is taking place (part 2). Finally, in part 3, we explore how heat is forcing the actors in the sector to question automatic ways of thinking about the functional resilience of rail.

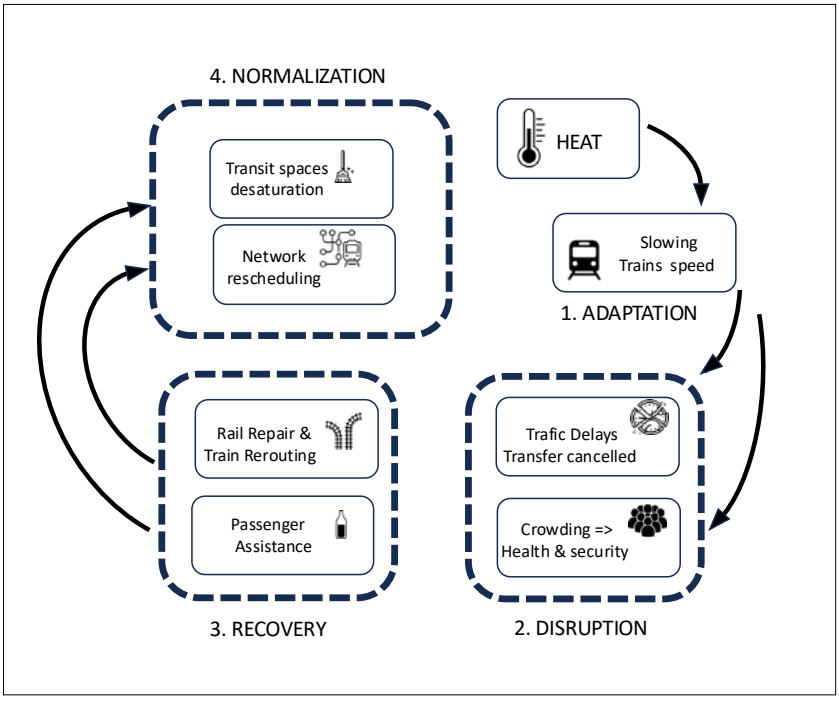
Heat brings disorder to stations

Let us begin with events that occurred on July 1, 2019 at Paris Montparnasse station. We chose this station because it is home to the regional and high-speed lines that serve the Atlantic beaches. The date was chosen because it was a day of major exodus, with more than 250 trains and more than 100,000 people travelling in scorching conditions that saw temperatures rise from around 30°C in the morning to more than 40°C in the afternoon.

The day began normally. The flow of passengers increased steadily as the cadence of departures and arrivals grew from 2 trains an hour in the early morning to 6 trains an hour in each direction. The first, fairly short delays (10 minutes) began from 11am on the suburban network. They increased to more than an hour, which is a long time for short-distance journeys. The delays snowballed because in many cases the same vehicles make the round trip on a line. The station level dedicated to suburban commuter traffic filled up, to the point that a dense crowd formed. Traffic became more difficult for a number of reasons. As the coordination between train arrivals and departures ceased, outgoing and incoming passengers travelling in opposite directions accumulated on the same platform, causing congestion. On the cross platform, there were many standing passengers, while others sat on the ground. This block the movement of people wishing to enter and leave by escalator or metro. The jostling and complaints rose to a crescendo. Towards midday, on the upper level serving interregional and high-speed trains, the same scenario was repeated: delays, initially slight, then more significant. Bodies squashed together, condensed into a crowd. Overheated air, heated emotions. Disorder.

From 12 noon to 7pm, the station operated below its normal standards. The different station personnel (Figure 1) applied two types of system. In the grey circuit, railway operations (signallers, maintenance teams, train

drivers and boarding equipment operators, under the supervision of the station's operational management centre) ordered trains to slow down and sometimes to alter their routes. In the people management circuit (white boxes), the reception teams (station information and security sections) were busy. The general security staff cleared clusters that presented a potential risk to emergency evacuation (approaches to the escalators, the metro entrances, the station doors which were jammed with smokers and people who had gone out for a breath of air as the wait dragged on). At around 5pm, the situation became extremely tense. In one place where families laden with children and luggage had being stuck for several hours, a suspicious item had been spotted. The "terrorism" protocol was applied: security perimeter, partial evacuation, dog teams, etc. A full evacuation of the whole cross-platform area and a train movement shutdown were just avoided when the father of the family came back to collect the bag within the twenty minute time limit. As people became overwrought (about missed connections, for example), or began to take the law into their own hands (on one train, stuck at a platform without air conditioning, passengers tried to break a window), a further level of the heatwave protocol was triggered: support teams distributed bottles of water on the commuter platforms, while others



1. How heat disrupts normal station operations

@ authors

steered vulnerable customers (children, seniors) to less crowded and better ventilated parts of the station. Hall 3 Vaugirard still had a few seats, whereas the main concourse had lost its waiting areas during the latest phases of modernisation. A few people nevertheless suffered adverse reactions to water stress, and the fire brigade and ambulance services were called out (Figure 1).

This case study shows how a station heatwave gradually takes on reality, consistency and form. Knox put forward the idea that climate change can be felt and understood through signs and clues (Knox 2020). In this sense, it could be said that the overheated station "embodies" an emergent urban form (or form of public transport) that is gradually making its mark on people's consciousness and practices.

In hot weather, a station ceases to be just a building and an organisation devoted to transport functions. It becomes a collection of objects and individuals forming an agitated, potentially simmering thermodynamic system, gradually driven to the brink of collapse in terms of both material processes and emotional reactions (Soppelsa, 2021). The disturbances are triggered by the obstruction to human and machine movements, and not simply by heat as measured by a thermometer. The disruption, in its consistency and reality, is contingent: it never takes exactly the same form or generates exactly the same disorders. Here are a few reasons why. First, if holiday home rentals did not all start on Saturdays, the stations would not be packed to the same extent. On a day of major holiday exodus, cutting train speeds has more serious effects than on an ordinary day, because the rail network is under greater stress. The heat triggers a series of cascading effects (e.g. passengers have to wait longer, get tired and are therefore more likely to lose luggage), but this phenomenon would not be so troublesome if very strict security protocols had not been put in place following the Thalys attacks in 2015. The spatial configuration of the station (more shops, fewer seats) reflects choices made in response to regulations specific to the European rail system (opening up to competition and the need to finance station operation through revenue from unregulated sources) (Baron 2019).

The architectural configuration of Montparnasse station, with its glass façade and vast hardstanding forecourt, accentuates the heat island effect, as does the closeness between bodies on the platforms, which generates excess anthropogenic heat (Requeña-Ruiz 2016). This would not have happened if the station had not been modernised and if the green surfaces on the forecourt had not been reduced to facilitate intermodality and access for people with reduced mobility. Finally, if the French rail network were not so old, speed limits would be less drastic, technical teams would have more confidence in the capacity of their equipment to withstand high temperatures, and delays would be less acute. In short, all the factors that came together on this particular day, arising from the interplay between climatic

and meteorological realities, architectural choices, legal frameworks and social and cultural factors.

At the end of the day, the fall in temperature allowed the network to pick up speed again and delayed trains were able to depart. The congestion subsided, the operational protocol for traffic disruptions was lifted and the situation returned to normal. But the exhausted passengers had two questions: in hot weather, why are trains always slower and why do stations become intolerable?

Thermal vulnerability of rail infrastructure

Let us now turn to the rail professions and explain the operating, maintenance and service choices that underpin the dual protocol outlined above.

When exposed to the sun, the railway's different components undergo damage and deterioration. In terms of degrees of vulnerability, it is primarily the electrical and electronic components (which govern the supply of electricity to the trains via the overhead power lines and which power the signalling systems) that are at risk of breaking down. Voltages on the power lines fall. Rising temperatures in exposed electrical cabinets along the tracks melt the plastic sheathing. Then, at ambient temperatures of around 40°C, metal parts become deformed: rails may burst into flames, train wheels or axles bend. Other factors (humidity levels, wear and tear on parts, steel quality, age and maintenance level of lines) also come into play. When these factors combine, the thresholds above which speed reduction is required to maintain the geometry of metal parts become lower (Dobney et al., 2009).

Rail regulators recommend these speed reductions because they know that heat is already responsible for around 20% of incidents and is sometimes a cause of accidents (European Rail Agency 2016, Villalba Sanchis et al., 2020).

As far as preventive maintenance is concerned, observation and inspection tours have to be conducted in the spring and throughout the summer to check for potential heat effects, and the network operator has to check the voltage in the overhead lines and the condition of the substations (Khah et al., 2021). Throughout the summer, maintenance workers and drones carry out surveillance rounds to monitor track geometry and to look out for fires (whether spontaneous or triggered by sparks as trains pass over the scrub on embankments).

In terms of operations, in line with international recommendations, the network operator (SNCF Réseau in France, Network Rail in the UK, etc.) imposes speed restriction criteria on companies. The critical rail temperature criterion is applied at various levels, but generally when ambient temperature reaches 25° to 30°C. When this level is significantly exceeded, the ultimate precaution is to close a section of line in order to avoid excessive risks of buckling and accidents (Thaduri et al., 2021). This type of decision was taken

for several routes departing from King's Cross and St Pancras in the UK on 19 July 2022.

When it comes to railway upgrade work (e.g. replacing track and ballast), heat is a major constraint. After work on the tracks, time must always be allowed for the ballast to settle and the track to stabilise. This delay becomes longer in the event of intense heat, which can have an impact on construction sites: worker layoffs, delivery delays and contractual penalties, not to mention inconvenience to travellers if the work is moved from the summer, when there is less traffic on suburban lines, to the autumn. In the UK, given Network Rail's own regulations, which state that track maintenance work must not be carried out when the temperature of the rails exceeds an ambient temperature range of 32°C to 38°C, Palin's calculations give two figures: 20% of summer workdays in the UK are already cancelled as a result of heat. This figure will rise to 40% by 2040 (Palin et al., 2013).

Finally, in the sphere of customer support, the operators' response also disrupts the business model of stations, which relies on commercial activity. First, because people are not keen to shop in a crowded, overheated station. Second, because heatwaves generate new logistics tasks and additional costs. SNCF has strategic stocks (100,000 meal boxes, 65,000 light snack boxes, 500,000 50cl bottles of water) to distribute to passengers in the event of system failures, delays or excessive waiting periods. In the summer of 2021 alone, one million bottles of water were distributed free of charge. In view of these soaring costs, the negative environmental impact of plastic waste and the risk of legal disputes with station retail outlets, the company is following the U.K.'s example by installing drinking fountains. The first prototypes were to be introduced in summer 2023 (Figure 2). The idea of a two-tier service is already taking shape: in addition to these public drinking fountains, the public-private holding company formed by SNCF Gares&Connexions and the Lagardère group, owner of the chain of Relay shops (which dominate the retail franchise market in French stations), high-speed rail or first-class passengers can obtain a free bottle of mineral water in Relay shops in the event of a heatwave by submitting a prepaid coupon with a QR code. In this, we can clearly see the impact of the marketing impulses that are very much present in the now public limited company SNCF.

It is not climate change alone that is affecting infrastructure; socio-economic, legal and technical practices and frameworks are both shaping and being shaped by the problem of heat. Emerging responses are found from within a repertoire of solutions that derive from the conceptual tools and modes of regulation and organisation that already exist in the company and its teams of engineers and managers (Baron 2021). Among the keys to this repertoire of solutions, two words come up with monotonous regularity: risk and resilience. But is that really what it's all about?

Heat: an infrastructure risk like any other?

The survey shows that heat brings into play a combination of technological realities and legal, social or economic factors specific to the railway world in France or in other advanced countries. The findings would be very different if we were dealing with the types of heat and investigating the assemblages that it forms in networks and stations in India, for example. However, all the world's railway engineers work within the same analytical framework. Their goal is to minimise disruption and return to a normal level of infrastructure functionality as quickly as possible. This section introduces and critiques the idea – and the very generic model – of infrastructure resilience.

As climate change begins to bite, heatwaves are becoming more sudden, more frequent and more intense, putting infrastructure at risk more often. Climate change is therefore a challenge for the railways. Could we see the development of a kind of gradual adaptation and resilience, in

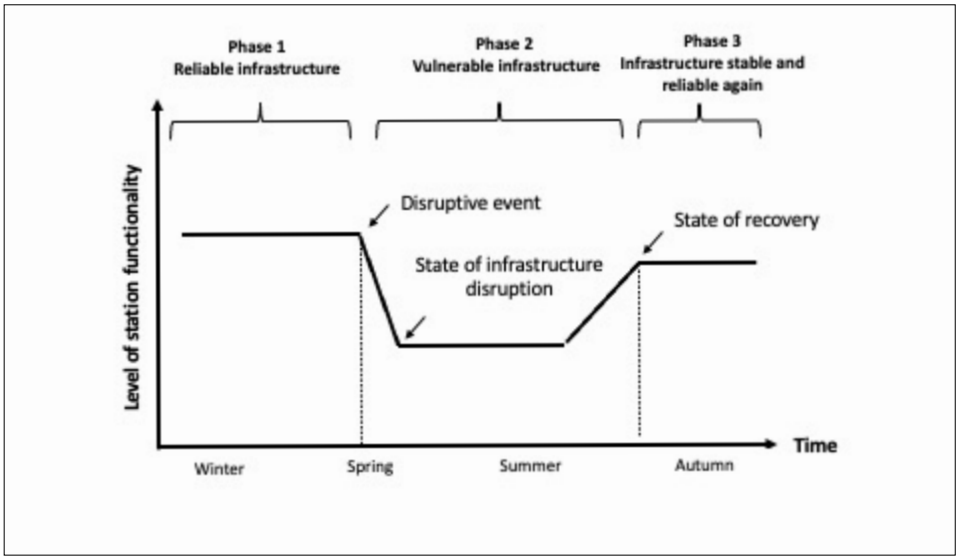
2. Prototype drinking fountain (pilot) to be installed in summer 2023 at Paris Est station

Photo : H. Zouad.

which everyone comes to terms with the situation and the protocols for managing disruption become routine? Yes and no.

On the one hand, the idea that the rail system is already absorbing and responding to seasonal heat increases has been demonstrated. Ferranti, working on retrospective data for the United Kingdom, notes that long-term adaptation to the gradual rise in temperatures, from spring onwards, has enabled the extended technological and organisational rail system to build up its capacity and avoid shocks and dramas. The author shows that, between 1980 and 2000, heat-related incidents occurred at the start of the hot season and much more rarely in August or September, although it can be just as hot at the end of the summer. On the other hand, this capacity for resilience is reaching a critical point, as sudden rises in temperature in spring prevent the technical system (and organisations) from adapting gradually. As a result, incidents and accidents are on the increase (Ferranti et al., 2016).

To go a little further towards understanding the challenges posed by heat, we need to take a step back from the resilience observed in infrastructure to the definition of the phenomenon itself in the professional railway community. For railway engineers, heat is one of a list of climate risks, along with storms and cold snaps. It takes its place among other natural risks (earthquakes), technological risks (cyber attacks, mass power outages, etc.) and health risks (COVID). The hazard is called a heatwave (high temperature, duration exceeding three days, low variability between night



3. Infrastructure resilience model

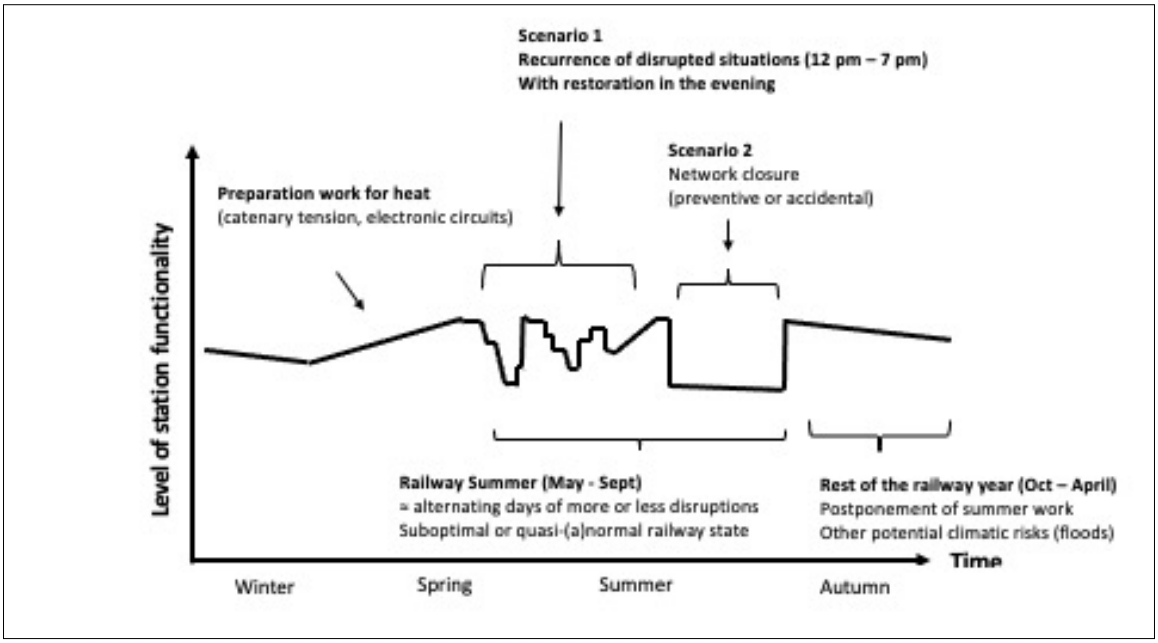
Source : adapted from National Academies of Sciences, Engineering, and Medicine (2021) p. 77, no further use allowed)

and day) or hot spell (if the episode is shorter and more intense) or heat dome (if it is longer and national or even continental in scale). It brings a dual challenge. On the one hand, heat exposes structures and equipment to damage: this is the challenge of accident prevention (safety). On the other hand, heat exposes people to physiological and psychological stress: this is the challenge of security (Singer and Raynor, 2016). Risk arises when the hazard and these challenges coincide.

Figure 3a shows the most commonly adopted model of resilience. The y-axis represents the level of functionality (of a station, for example) and the x-axis represents time. The flat line corresponds to the morning phase of normality, while the disruption appears at midday: from midday onwards, the event causes a loss of functionality marked by the downward line. The recovery protocols described above are part of the so-called recovery phase (preventive slowdowns and palliative support services), and the line rises until it is flat again, indicating stable, normalised operation.

Let us now compare this generic figure with figure 3b, which we drew to represent the empirical experience of the big holiday exodus day.

– The preliminary state is not a straight line, since the railway system's robustness is reinforced in spring, hence the small drop along the y-axis.



4. Model of railway resilience to heatwave risk.

Source : authors

- The disruptive event is not the heat, but its consequence, i.e. congestion on the network and at the station, with all its direct and indirect effects.
- The loss of functionality is not sudden because it is not the product of a single event (as would be the case if an overhead power line snapped) but of a succession of slowdown decisions that create gradual disruption. The line dips and then rises in steps.
- Recovery is not represented by a flat, stable line, because the following day, other structural slowdowns may occur: they affect fewer people, but cause delays and therefore losses of train functionality and regularity. In addition to this V-shaped line, there is another type of potential disruption in the form of a U-shape, where there is an actual occurrence of track buckling or a decision to shut down the network.
- During the autumn, the line shows something of a zig-zag as it catches up with summer maintenance work and reflects postponed delays and disruptions.

All in all, if heat were a shape, it would not be a single V as in Figure 3a, but a wave marked by repeated, more chaotic ups and downs.

By distinguishing between the two graphs, we can better identify the reasons for misunderstandings about the role of heat and the difficulty of "infrastructuring" it (Graham 2015) when it comes to stations.

- in terms of causality: it is not the heat, but all the decisions and action taken because of heat that undermine the operation of a station or network.
- in terms of temporality: heat is not an isolated event (like a temporary fault) but an environment. Over time, the resilience model becomes less applicable as climatic conditions in stations force them to operate at high temperatures for weeks on end.
- in terms of outcome: the idea of an infrastructure recovering following a heat hazard needs to be rethought. This problem cannot be solved as simply as repairing an axle or even rebuilding after an earthquake. Heatwaves in stations cast doubt on the idea that the infrastructure system can be entirely controlled (Helmrich and Chester 2020). The return to normal is also a matter of patience, reliant on a drop in temperatures and the end of a new risk period – the railway summer (in the 20th century, conversely, engineers made plans for "extreme cold" and explored ways for train drivers to detect and avoid snow drifts). The challenge of getting through a type of summer which is only just beginning to be glimpsed in its temporal, spatial, material and human substance (Markolf et al., 2019) is one of which station managers and users are increasingly aware.

So heat (no longer in exceptional waves but as a new way of experiencing stations) reconnects questions of safety and security. It blurs the boundaries between one-off and permanent threats. It brings to the fore

issues of authority, influence and domination, issues that can be encompassed by the idea of a climate regime. In the literature on sociotechnical infrastructures, a regime is understood as a certain type of established order, a system that enlists technologies and artefacts (in this case, stations as places and as organisations) to achieve or maintain positions of knowledge or power. Gopakumar for example shows how, in Bengaluru in India, the fluidity of transport systems is not so much an operational goal as a value adopted to serve an idea of urban performance. By presenting congestion as a major risk, the authorities are in fact preparing the ground for the removal of a host of poor people from the city centre and the subsequent capture of land rent (Gopakumar 2019). Applying this techno-political approach, one might wonder what – in the balance of power between transport and urban actors and users and taxpayers, who are often told that the climate "demands" strong, vertical decision-making (Karvonen 2020) – is being protected by the presentation of heat as an infrastructural risk.

The effect of heat is to disorganise and create internal tensions in a railway company with multiple interests. Indeed, the decision to enforce slowdowns shows that the network operator's priority is the integrity of its infrastructure. This is not a neutral choice and is not based solely on scientific knowledge about the ductility of metal. The national rail network is a public domain that operates under the authority of the infrastructure operator. Maintaining its economic value, which is inversely proportional to the degree of wear and tear on it, is its existential raison d'être. Protecting the integrity and market value of this network prompts it to prioritise slowdown decisions which – rather than heat – are the direct cause of the entire sequence of disruptions observed. The choices made by the infrastructure operator can be detrimental to the equilibrium (and long-term viability) of transport operators or rail regeneration companies, which incur financial penalties, and they can obviously cast a shadow over Gares&Connexions, which has to deal directly with dissatisfied customers.

In this sense, heat applies a litmus test, as Martuccelli puts it. It opens a window of time during which knowledge actors (engineers), entities within the railway world and, more broadly, society (government, public opinion, train users), modify the experience of a public problem and employ contrasting representations of what heat is and what rail transport is. In our case study, a station in a heatwave produces a crisis in the ways heat is understood (as a fact and an experience, as a sensory and rationalised reality, and as an individual and collective phenomenon). It challenges the facts and the relationship to information. The climate regime of infrastructures will therefore probably be a time of controversy, particularly when the current responses demonstrate their inadequacy (e.g. scandals arising from passenger deaths) or when preventive choices (such as the prolonged precautionary closure of networks) are perceived not as wise decisions but as forms of impotence or unpreparedness.

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Positioned at the interface between engineering and sociotechnical perspectives, this chapter shows that the adaptation of stations to rising temperatures raises questions of public interest, in which technology, space, professional organisations and many other dimensions of station life are tightly interwoven. By tracking heatwave incidents and operators' responses to them, it shows how environmental trends are interwoven with technical and organisational choices.

From a theoretical point of view, the heuristic interest of this study lies in the fact that it proposes the concept of thermal regime as applied to stations and its problems, limitations and contradictions. It emphasises how rail actors are locked into ways of doing and acting that focus on the artefact, and how railway operation and thermal vulnerability are shaped by each other. It offers a critique of the conceptual tools that underpin the idea of resilience as employed by the operational rail actors. This chapter shows that, as the climate heats and thermal regime of stations changes, a litmus test is emerging. The two countries studied are at different stages in the process. In France, it is only just emerging, whereas it has gone further in the UK. This is because, across the Channel, the summer of 2022 was exceptional in terms of weather, and the choices made reopened other debates: on the dilapidated state of the network and the legacy of the Thatcher years, on the legal relationship between the public operator and the private companies in a context of quasi-renationalisation, and on the role of other social actors (urban and health professionals, train users, taxpayers).

The length of the text, with its focus on the immediate handling of heat in stations, prevented us from including a section on bioclimatic responses, which obviously fall within a different timeframe, the domain of longer term planning. Greening projects within or outside passenger buildings connect with the chapter on Japanese eco-stations in this book. Discussing the greening of stations is a valuable exercise, but it does not resolve the questions raised here about changing the infrastructure regime, for three reasons that we will briefly outline.

First, green facilities are not innovative. In fact, there has been something of a decline in station gardens and fountains in recent decades (although the trend appears to be reversing). Second, the bioclimatic artefacts (trees, green walls and roofs) are very small: they provide a few minutes of cooling for some of the people who will be waiting longer for their train. They do not mitigate the fragility of the rail infrastructure in heatwave conditions. Finally, bioclimatic design is simply another of the service-focused solutions considered in this chapter in that it forms part of the status quo, i.e. an a priori assumption about the stability of the rail system as a whole, which may well be shattered by the scale of future climate disruption.

Part 2.

Metabolisms and Circularities

Railway architecture and its reuse: A materials approach to its history

Pauline Detavernier
and Alexandrina Striffling-Marcu

This chapter is the second part of an ongoing research project (Detavernier, Striffling, 2022) which aims to explore an area of railway history that to date has received little or no academic attention: the reuse of construction materials and the history of this practice within the French railway network, compared with certain European examples. As researchers and architects who have worked for the AREP agency – the SNCF subsidiary responsible for the design of its parent company's mobility spaces – we are interested in the history of this practice because it resonates with an operational initiative called REAP that has been under development in the agency since 2018.

The aim of the REAP (REemploi Appliqué – applied reuse) team is to establish a framework for practices of reuse, to facilitate them within the agency's projects and to encourage thinking about the SNCF network as a source of materials. This reflects the agency's commitment to low-carbon architecture and frugal construction. By saving the energy needed to manufacture new structures, reuse provides one of the answers to the environmental challenges facing both the construction and transport industries.

REAP has observed that the potential for reuse is huge, since SNCF sites form a network that covers the whole country. But this potential is not just an appropriate contemporary response to ecological demands; it is something that the companies have engaged in since their beginnings. In what circumstances and in what ways did reuse evolve in the railway industry? By exploring this genealogy of railway reuse, we can contribute to scientific thinking about emerging architectural practices in the sector.

We will begin by situating railway reuse within the context of existing practice and within a broader history of reuse in architecture. We will then analyse the characteristics of this practice through the prism of materials. This approach will provide context for past reuse initiatives in the history of railway construction, while at the same time highlighting the timeless technical specificities of these materials, which continue to challenge the new players in this field

Definition and historical benchmarks of reuse: a review

For Jean-Marc Huygen, "reuse is the act of giving a new purpose to an existing object that has fallen into disuse and lost the use for which it was designed and made" (Huygen, 2008, p.11). This definition thus differs from the contemporary "reuse, recover, recycle" trio. By preserving the whole object, reuse in our sense maintains the memory and the history of the artefact (Gasnier, 2018).

In this article, reuse is taken to mean the use of the same materials or construction elements on successive occasions and on different projects within the railway sector, each time in a new role. Several scales of reuse are considered here, from the crossbeam that forms the infrastructure to the building in its entirety. By choosing a broad definition of the notion of reuse, our aim is to understand how this practice addresses the technical, social, economic and behavioural dimensions of the act of construction.

The scientific literature on the practice of reuse and the issues it raises for society has developed significantly over the last twenty years in Europe. Doctoral papers with abstracts containing the term "reuse" appeared in the early 2000s and the instances of such research increased significantly between 2010 and 2020 (thèses.fr). Though relatively recent as a topic of academic research, reuse is a practice with a long pedigree. In the field of construction history, this notion of reuse (or replacement) has been an integral part of building practices since the earliest vernacular buildings (Choppin and Delon, 2014). Although this is not always the term used, the operational realities very much reflect this practice, i.e. the dismantling of existing materials that have fallen into disuse so that they can be put to new use in a new building.

In the Middle Ages and until the start of the industrial era, reusing materials was the norm; a form of discernment prevailed, and old materials were sometimes even preferred because "they had proved their worth" (Choppin and Delon, 2014, p.40). At that time, it was cheaper in every way to reuse a material, as the estimated resale price was greater than the cost of dismantling (Ghyoot et al., 2018). As a result, demolition sites were more like removal sites: workers would begin at the top of the building, gradually working their way down using tools designed for the careful disassembly and repair of materials. These were then sold either retail or wholesale – Achille Picard was the leading contractor in this field at the time – for use in other buildings.

From the nineteenth to the twentieth centuries, a sea change occurred: the emergence of new materials, health concerns and consumerist capitalism made reuse synonymous with poverty (Huygen, 2008). Mass production brought with it the idea that we should throw away what we no longer use in order to consume more and thus keep the economy spinning (Bouchain, 2006). Discernment gave way to a frantic race for growth, production and speed. The previously positive economic balance of reuse was reversed:

the cost of removal added to the cost of construction work. The practice demanded too much space and too much time, whereas the resale price of materials was no longer sufficient to offset the cost. Buildings were therefore demolished using newly developed machines dedicated to speed, and materials were reduced to waste (Ghyoot et al., 2018). The wrecking bar, a steel tool with a flattened end used to loosen masonry walls, was replaced by the wrecking ball, invented by the brothers Jacob and Albert Volk in the late 1920s (Ghyoot et al., 2018).

But in the light of the new imperative to make our built worlds sustainable, established as a new paradigm by the Brundtland Report (1987) and a major challenge for 21st-century architecture, this neglected practice is now back in the spotlight.

Within this history of reuse, there is little mention of the railway world. However, the development of the railways opened up the possibility of a scale shift in the practice of reuse, by enabling materials to be transported further and in greater quantities. Julien Choppin and Nicola Delon explain: "The railways would soon revolutionise the building industry. The first transfer of an entire building was that of the north pier, built in Paris in 1846" (Choppin and Delon, 2014, p.70).

In seeking to understand the scope and evolution of the practice of reuse, facilitated by the railways and practised but little documented, we nevertheless need to take into account the constraints associated with the materiality of buildings. The examples set out below, grouped by type of material (wood, stone, metal), situate this practice within the history of railway architecture, highlighting key moments in that history.

Wood: the amaterial of the temporary, the removable

Wood in railway construction is often associated with temporariness. This association is reflected in the confusion surrounding the first boarding stage at Saint-Lazare station in Paris, which historians wrongly believe to have been built of wood, probably because it was originally described as a "temporary boarding stage" (Paques, 2021).

Wooden buildings are easy to dismantle, so timber was initially used in the early days of railway architecture in France. Its relative cheapness and speed of assembly encouraged the construction of many so-called "temporary" boarding stages or wharfs: the term, common in the nineteenth century, illustrates the temporary nature of buildings erected on a moving network. This type of building very quickly caused problems as passenger flows increased and the technical infrastructure developed.

> "In the 1850s, most passenger stations were "rudimentary". Many were simple shacks. [...] In 1857, the Minister demanded that the temporary stations be abolished. In the western suburbs, on both the right and

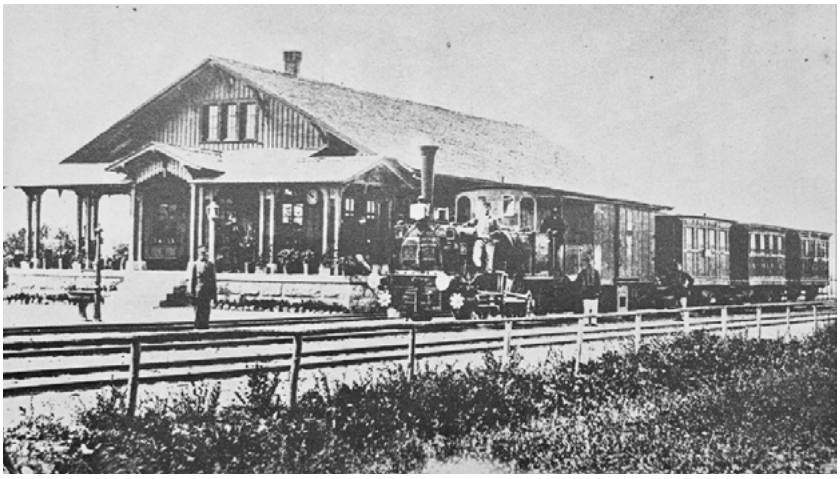
> left banks, the need was urgent: the stations at Courbevoie, Puteaux, Suresnes, Ville d'Avray, Clamart, Meudon, Sèvres and Chaville were rebuilt between 1855 and 1858. The same was true for the North. In the Midi, the stations at Agen, Bayonne, Dax and Valence-d'Agen were dismantled and rebuilt" (Caron, 1997, p.317).

The mass replacement of these wooden boarding stages by more permanent passenger buildings, often of masonry construction, has left few examples of these structures still visible today. The landing stage at Gravelines (Nord) is the only building protected as a historic monument. Timber was not just used for temporary purposes. The wooden station at Cauterets (Hautes-Pyrénées) was built in Bordeaux by the Carde company, dismantled, transported to the site and reassembled piece by piece. While such experiments with new, prefabricated wooden passenger buildings were conducted during the development of the rail network, the same network logic also applied to reuse. In this respect, it is interesting to see how the Paris-Cherbourg line developed from its original concession in 1846. The first section of the network to be built had a terminus at Caen station, where a temporary boarding platform was built. When the branch line to Cherbourg opened in 1860, Saint-Lô station was erected as the new terminus. The temporary boarding platform at Caen was removed to make way for a more permanent structure, and the timber was transported by train to serve as the structure for the new Saint-Lô station.

As the rail network was consolidated, the status of stations on the network changed, and the newly created rail system was used to transport reused materials. Moreover, our initial research suggests that the major historical phases in the history of reuse, as mentioned above, were clearly represented in the French railway world, as well as abroad. In Switzerland, between 1865 and 1875, Lucerne's temporary wooden railway station in the Maihof district became obsolete. It was therefore dismantled and its buildings reused elsewhere, for example in the first railway station in Bülach (Figure 1).

In the Netherlands, while private companies built lavish stations on the country's main line (Amsterdam-Harleem), the western branch (Utrecht-Rotterdam) was much stingier. There were no 'visiting card' stations for the private company here, as its financial difficulties prompted a more economical choice in the reuse of wooden buildings. The stations at Woerden, Oudewater, Nieuwerkerk, Capelle and den Ijssel were built in the 1860s from wooden huts initially intended to house the management offices. Rotterdam Maas station was built in a former railway shed, also made of wood, purchased and refurbished for the purpose.

In the case of Woerden station in the Netherlands (NS, ProRail, Spoorbeeld, 2017), there was no alternative to the use of wood, because of its location: a fortified town, Woerden chose a site for its station just outside the city walls. The law stipulated that within firing range (i.e. a 300m strip on either side of the ramparts), "only wooden buildings and other structures



1. Bülach railway station 1865-1876, formerly in the Maihof district

Source : Compagnie des Chemins de fer de l'Ouest (1867).
Série des prix, " Charpente. Ouvrages en bois vieux " : 93. BNF/Gallica.

that could be quickly dismantled in the event of war were permitted" (p.7). The building was not replaced with a masonry station until 1911.

As with this last example, timber appears to have been the first construction material that could be reused across an entire railway network. Reuse therefore fulfilled a twofold purpose for the companies: temporal discernment (the temporary station), coupled with a form of financial frugality.

The economics of rail reuse can be observed in the sites themselves. The Price Series published by the Companies are a source of valuable insight into the economic implications of reuse. Drawing on the example of a Price Series as applied by the Compagnie des Chemins de Fer de l'Ouest in 1867, it appears that two types of dismantlement were envisaged:

– on the one hand, careful removal is costed, possibly including disassembly of the parts and cleaning, then lowering of the material to the bottom of the site using ropes;
– on the other hand, a rougher form of removal is also mentioned "with dropping rather than lowering", a necessarily less expensive because less cautious practice.

To give just one example, oak timber that had been dropped rather than lowered was worth one and a half francs less per cubic metre. Subsequently, the reuse of materials from careful demolition work is also costed. The extra cost involved in removal and storage could therefore be offset by the substantial savings achieved in avoiding the purchase and supply of new material. The decision between one or other of these dismantling options, and whether or not to reuse, was therefore based on financial considerations (table 1).

Example of timber frames, Price Series, as practised by the Compagnie des chemins de fer de l'Ouest in 1867.

Removal of unassembled oak or fir timber, including lowering by rope or goat, moving from a distance of 100 metres and storage.	3,50 F per m^3
Removal of assembled oak or fir timber, including disassembly, lowering by rope or goat, moving from a distance of 100 metres and storage.	5,50 F per m^3
Removal of oak or fir timber, assembled, with dropping instead of lowering.	2,00 F per m^3
Removal of unassembled oak or fir timber, with dropping instead of lowering.	4,00 F per m^3
Reuse of oak or fir timber framing from demolitions, including cutting, filling in old mortises and notches, moving from a distance of 100 metres, lifting, assembly and installing, as well as supplying pin nails and rough shims. No assembly.	10,00 F per m^3
Reuse of oak or fir timber framing from demolitions, including cutting, filling in old mortises and notches, moving from a distance of 100 metres, lifting, assembly and installing, as well as supplying pin nails and rough shims. With assembly.	30,00 F per m^3
New oak or fir timber (depending on squareness)	Entre 100,00 to 200,00 F per m^3

Source : Compagnie des Chemins de fer de l'Ouest (1867).
Série des prix, " Charpente. Ouvrages en bois vieux " : 93. BNF/Gallica.

Longevity is sustainability: the reuse of stone

Stone gradually replaced wood as the rail network's stations become more permanent: "In the construction of buildings, materials that were too fragile were gradually abandoned. In fact, masonry was cheaper than simple wooden frames filled with bricks" (Caron, 1997, p.319). The reuse of stone was less common: unlike wood (and steel, to which we will return later), whose primary components can be assembled using so-called "dry" construction techniques, stone requires a mortar-type binder, making removal trickier and more risky. Its weight also makes it difficult to handle and transport. Yet this "inert" material was nevertheless sometimes reused because of the durability and longevity of stone.

The existing façade of Lille-Flandres station is a typical example. The first Gare du Nord station in Paris was designed by the architect Léonce Reynaud and opened to the public on 14 June 1846. When design work for Jacques-Ignace Hittorff's new Gare du Nord passenger building began in 1858 (the building as we know it today was opened to the public in 1864), stone construction was only twelve years old. In parallel, these were the same years (1860-1864) when discussions were underway over the expansion of another mainline station, Lille-Flandres (Bowie, 1987). These were the circumstances in which the Compagnie des chemins de fer du Nord came up with the idea of reusing the façade from the Paris station, which was dismantled stone by stone and carried by train to Lille to be reused.

At a meeting of Lille city council on 22 February 1864, the content of the proposal by the Compagnie des chemins de fer du Nord prompted general indignation: "The public is asking whether these castoffs from the capital constitute a truly monumental station, when no columns, porches or canopies have been added." The stones from the façade of the Gare du Nord were numbered and their positions recorded, before they were removed and transported by train to Lille at the other end of the line (Figure 2).

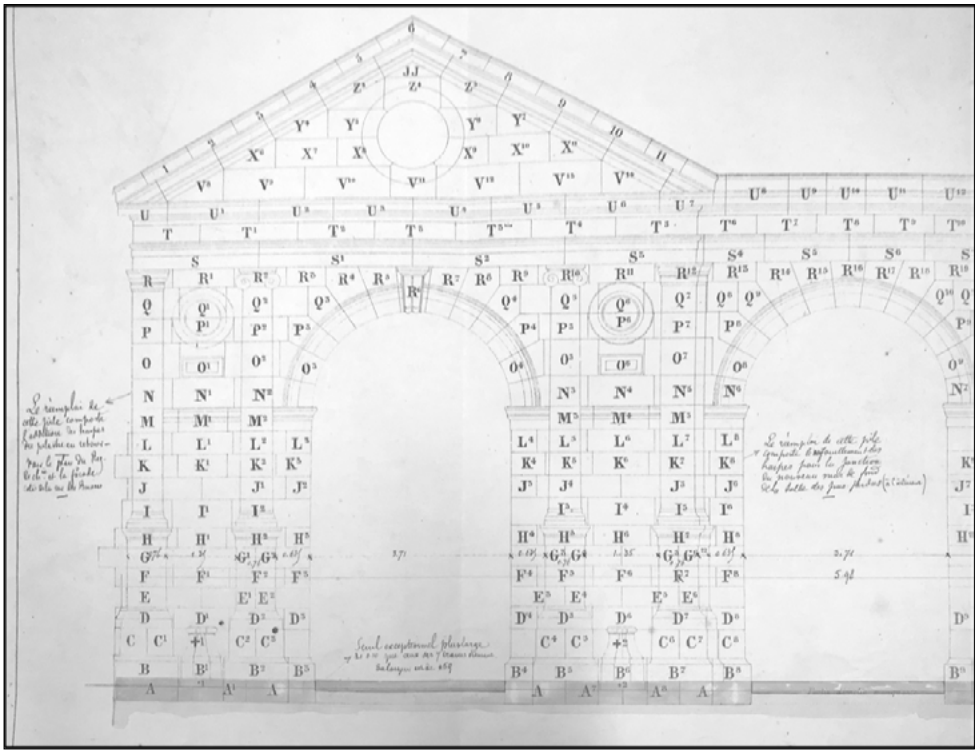
In order to give the people of Lille the monumental appearance they wanted, the old façade was modified by adding a further storey, as well as a clock, an urban signal of railway exactitude (Figure 3).

This adaptation entailed the creation of a symmetrical central section and the addition of a pillar to the reused façade, resulting in an odd number of arcades. The graphic documents for the project employed a special colour code, in which hatching on the plans and elevations marked "the parts of the existing building with which we are connecting", black signalled "the parts of the building to be made of materials from the Paris station", vermilion "the part to be made of stone masonry", and finally pink for "the parts to be made of brick" (Plan du Rez-de-Chaussée projeté, 1865, Archives SNCF). In fact, only the façade was made of stone, whether reused or new. The brickwork interior partitions were attached to the rear, requiring adjustments to the material brought from Paris. The elevation thus specifies that "the reuse of this pier requires the scouring of the harps on the inside to link up with the new finishing wall of the waiting room" (Élévation de la façade de l'ancienne gare de Paris […] avec indications spéciales relatives à l'agencement des nouveaux seuils en pierre de Soignies, 1864, archives SNCF).

Finally, these documents also help us to understand why the thresholds had to be adapted to the height of the ground in Lille: the first masonry bed was half-buried, and "new sills in Soignies stone" were laid over the "Paris timber" threshold.

These adaptations demonstrate the craftsmanship needed in the use of materials, which entailed much more than simply restoring an identical product.

The reuse of the Parisian façade is mentioned several times in scientific studies tracing the history of Lille-Flandres station (Lussien-Maisonneuve, 1980). These archive documents give us a better understanding of the challenges and practices as well as how they were handled. They also tell us that it was not just the façade that was reused, but also a number of related elements, such as the artificial lighting system: two stars and fifty metres of "old pipework restored and re-installed" " (Élévation à main levée de la façade de la gare de Lille-Flandres avec indications spéciales relatives au réemploi des illuminations de l'ancienne gare du Nord à Paris, 1868, archives SNCF).

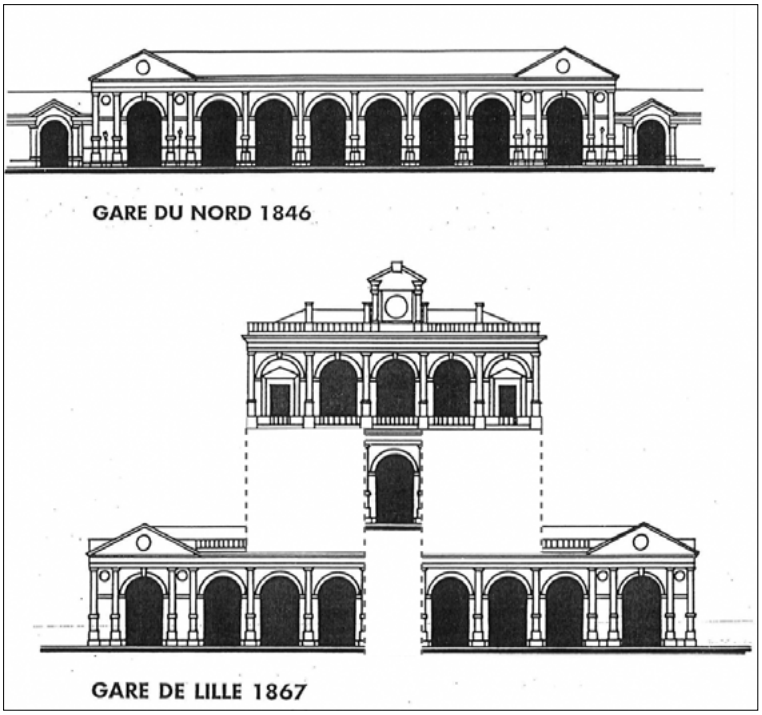


2. Extract from the elevation of the façade of the former Paris station, 1864

Source : Archives SNCF, AREP, Lille, SNCF00007001.

In addition to the well-documented reuse of the façade in 1864, the archive documents also reveal some previously unpublished information about the recurring practice of reuse in Lille-Flandres station. The graphic documents produced for the various phases of the work to expand Lille-Flandres station explicitly mention the interior fittings and furnishings to be removed and reused in existing spaces. In 1868, the reception hall renovation plan called for "reused marble fireplaces", while the plan drawn up in 1888 stated that "the windows on the demolished façade [...] will be reused". Doors, fireplaces, workbenches, stoves, slates: a multitude of existing components were designated for reuse in this phase of the works.

The data from Lille-Flandres confirms that reuse was not a marginal practice in the construction of that station and also leads us to assume that – far from being an isolated instance – this process was part of a structured system. The historical documents, for example, specify that certain items were to be transported to a storage location. Annotations such as "chimney to be dismantled and stored in the warehouse" or "the existing chains will be carefully removed [...] and sent to the Paris warehouse for reuse" imply that materials were being moved to centralised storage facilities or warehouses.



3. Modifications made to the former façade of the Gare du Nord station in Paris for its reuse in Lille

Source : History of Lille Flandres station, AREP archives, Paris, 1992).

On a smaller scale, the example of Epinay-Villetaneuse station shows diversity in the reuse of both stone and iron on a platform shelter in 1898 during a project to lengthen the underpass, sourcing materials from the station itself (in-situ) and from another station on the network (ex-situ).

Like Epinay-Villetaneuse station, which had to adapt to accommodate a new track and platform, increases in traffic or in the network itself led to regular expansion work on railway passenger buildings. It was not uncommon for building components to be relocated a few metres away, a form of in-situ reuse. Here, a masonry gantry was to be "demolished and rebuilt" at the new end of the underpass. The new gantry, "made with reused materials from the demolished gantry on the current second platform; except for the back wall gates and frames, which will be supplied new", retained the same dimensions at 38 metres long (Plan d'allongement du passage souterrain. Ensemble des nouveaux abris sur les quais, archives AREP, 1898).

Alongside this change of position, the creation of the new platform demanded the building of new facilities: a gantry was added "in new materials except for the stairway shelter partitions". The metal frames for these glass partitions were salvaged from another station in the Chemins de fer

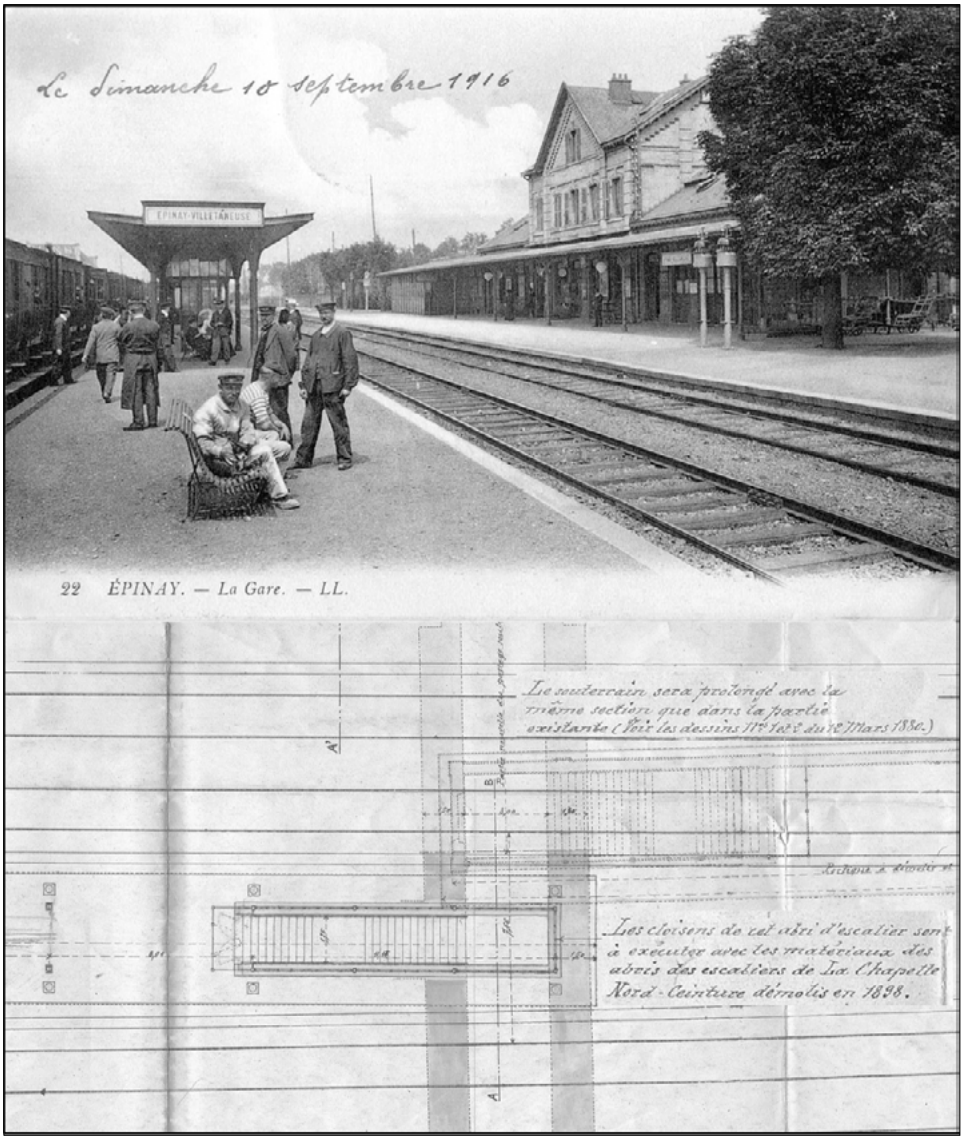
du Nord network, La Chapelle Nord-Ceinture, where similar shelters were demolished in the same year, as shown in the plan extract below.

Here, as in the case of Lille, we can see how important it was for builders at the time, and for researchers today, to make annotations on plans. These explain the colour codes (for demolition, preservation, construction) and document the movement of materials on the network (provenance and storage). In this specific case, ex-situ reuse seems to have been made possible by a form of standardisation in the metal platform shelters across the network, which would appear to have been manufactured in series and hence to be interchangeable (figures 4 a and b).

Iron: standardised and adaptable structures

The use of iron in the railway sector, for both buildings and infrastructure, reflects the progress of technical development arising from the mastery of this material in the nineteenth century. Its use was intrinsically linked to the development of the train, to such an extent that "at the height of the French rail effort, between 1850 and 1880, this sector [absorbed] almost a quarter of national iron production (and up to 80% of steel production once that too reached the industrial stage), a proportion that has remained unmatched since then by any other sector, including the car industry" (Benoit, 1994, p. 99). This massive output of iron followed the introduction of new technical processes, such as rolling, which was used for both rail manufacture and construction. The ability to produce standard parts brought flexibility of use. Urban construction (including the building of railway stations) and railways were the two sectors with the highest demand for iron. These "two markets [...] were technically close and often even parallel, insofar as the matching production [...] was frequently carried out by the same factories" (Benoit, 1994, p. 101). The increasing use of iron in construction gradually made it the dominant material in the sector, since it was easier to handle than stone.

In buildings, the capacity for longer spans meant that larger, lighter structures could be designed. The industrialisation of building components and assembly methods made structures easy to dismantle and reassemble. For this reason, there are a number of examples of the reuse of metal halls, structures that were so adaptable that the assembly plans sometimes remained the same from one site to another. A notable example is the big passenger hall (Émile and Veston, 2020) in Saint-Germain-des-Fossés,



4. Epinay-Villetaneuse station in 1916 and extract from the "Underpass extension plan. Set of new shelters on the platforms"

(Top) Postcard of Epinay-Villetaneuse station in 1916. On the platform, the new shelter built from recycled materials according to plans drawn up in 1898.
(Bottom) Chemin de Fer du Nord, Epinay-Villetaneuse station, extract from the "Underpass extension plan. Set of new shelters on the platforms"

Sources : AREP Archives, 1898.

which was reused in Valence. The name of the first station was simply crossed out on the official documents and replaced by the second.

In addition, the halls were also dismantled in such a way as to keep them intact, even without being allocated to a specific new location. The structural elements were then stored, as in Nice, where the hall of the former Gare du Sud station was removed and placed on standby in storage rather than demolished (Figure 5).

As with wood and iron, examples of the reuse of steel elements can be found outside France, and this European perspective shows the predominance of historical examples of reuse for steel structures compared with the two earlier materials. Examples include Valencia-Alameda station (Spain), the passenger hall of the former Gare du Sud in Nice and the Champ-de-Mars boarding platform (France). Because of their large size, these types of building were ideal for industrial reuse. The large passenger hall at Valencia-Alameda station was repurposed as a chemical production plant, while the Champ-de-Mars arrival concourse was converted into an electric train terminus and then a workshop.

The development of rail infrastructure facilitated by the production of standardised parts was also a source of large quantities of usable material. The economic constraints of railway operations sometimes forced railway companies to be ingenious in their reuse practices. This was particularly true for the cash-strapped Midi region, where worn rails from its network were used to create ogival catenary gates, which can still be seen on certain routes such as the Bordeaux to Arcachon line.

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This article looks at the history of railway reuse through the prism of materials, situating this practice within the evolution of station construction techniques since the nineteenth century. Indeed, while each of the structural materials mentioned (wood, stone, iron, steel) may be characteristic of a particular period in the history of the railway, the issues raised by the reuse of these same materials are, so to speak, trans-generational. Even today, REAP teams face structural, technical, regulatory and organisational constraints associated with the reuse of different materials.

This historical approach to reuse in the railway sector also shows us how the application and acceptance of this practice have evolved: although it waned in the twentieth century, the examples described here nonetheless bear witness to its continued existence in the rail sector since the advent of the railway.

A further dimension is also highlighted: the orchestration of practices at regional level. Archive documents show that reuse was structured, quantified and spatialised. The railways made it possible to extend this practice over longer distances, from one station to another. It also offered

5. Elements of the hall of the former Gare du Sud, removed and stored in Nice.

the possibility of centralising available materials by transporting them to railway company depots. This system was organised in a way that the REAP team is now attempting to reproduce by creating SNCF reuse platforms. Understanding this forgotten operational system, which is in many ways similar to modern approaches, can shed new light on the issues surrounding reuse in the construction industry.

In this respect, the task now is to situate these reuse initiatives within a hierarchy of priorities. Environmental objectives, which provide a strong argument for this practice, sometimes run up against the counter-priority of preserving the heritage value of railway buildings, some of which have been in place for over 150 years. “What are the relations to space in these recovery practices? What are the relations to time? How do these practices modulate the historicity and geography of places [...]?” (Choppin, Delon, 2014). These questions underline the fact that, for these two conflicting priorities to be reconciled, we need to assess the value of entire buildings before the value of the materials used in their construction. Today, reviving the practice of reuse is part of a drive to restore sustainability and frugality to the act of construction. The process of deconstruction must therefore serve these goals by structuring and adapting this practice to the challenges of today

Potential and limits to the recovery of excavated material from the Grand Paris Express metro system

Salwa Cherkaoui El Baraka

At last in the history of urban construction, the topic of excavation spoil has come into the limelight, notably in the context of the Grand Paris Express project, for which 47 million tonnes of materials (earth, rock, etc.) will be excavated. Voluminous to store, intricate to move and complex to process, these inert materials are a problem: the issue of their transport and storage has generated fierce local controversies, particularly in Seine-et-Marne and Essonne. Paradoxically, the construction industry faces almost symmetrical problems: the rising cost and increasing scarcity of building materials. These two issues have prompted the emergence of an initiative entitled Paris des déblais [Earthworks Paris]. Société du Grand Paris, the company tasked with the Grand Paris Express project, issued a call for tenders inviting engineers and researchers to propose ideas for recycling construction waste (by mechanical processing) and reclassifying it (legally and symbolically) as a resource for use in new building or public works projects in the Paris region.

As a researcher and architect, I conducted an investigation into the definition of these inert materials as geo-sourced construction materials. I tracked the responses to the aforementioned call for tenders, I visited several exhibitions, the most recent of which was the Biennale d'Architecture et de Paysage d'Île-de-France (spring 2022, theme "Soil and cities") and in particular studied the start-up conditions for the Cycle Terre ecological demonstrator created in autumn 2021.

What are the right scales of governance for an urban metabolism policy, and to what extent does the spoil emanating from these huge station construction projects in Greater Paris give us reason to believe in the virtues of circular urbanism? The first part of this chapter follows the research path opened up by Bastin (2019) and applies theoretical framework of sociotechnical innovation (Geels and Schot, 2007) and the notion of innovation niches (Savini and Bertolini, 2019). Part 2 describes the efforts made and the difficulties encountered by Société du Grand Paris

in moving away from a highly linear model of materials production, storage and reprocessing, while the final part shows the difficulties of reusing these materials in the case of a construction project in Seine-Saint-Denis (part 3).

What should be done with the excavation spoil removed from underground sites?

A question of industrial ecology

The concept of urban metabolism refers to "all the processes by which cities use, consume and process natural resources" (Barles, 2008, p. 21). This idea suggests the possibility of imagining materials from the soil being able to physically circulate (be extracted, transported, processed, used, etc.) and to vary in their ontological status (being defined alternately as material or as waste). In terms of volume, this excavated material is one of the principal types of urban waste (Augiseau and Barles, 2017), and the quantities that specialist contractors are asked to handle fluctuate in time with urbanisation processes and metropolitan megaprojects (Augiseau, 2020; Augiseau and Kim, 2021). Their proliferation and dispersal in sometimes protected areas, and the damage they can cause, are also issues of public concern (Bastin and Verdeil 2020). Strategies are therefore needed to recycle them and integrate them them into industrial and commercial circuits, and hence into urban metabolism as a whole.

At a time of growing concerns about the environmental impact of buildings, the concept of circularity refers to the application of metabolism to this part of the construction process, coloured by the positive associations attached to innovative processes and practices. Following the European Circular Economy Action Plan of March 2020, many efforts have been made to apply the idea of circularity to road building, or to the construction of buildings for different purposes, for example by the use of raw earth. The idea of converting one contractor's waste into resources for another conveys the notion of synergy. The terms often used for such practices are "upgrading" or "reuse", but they are gradually acquiring a meaning that is distinct from the ideas encapsulated in the common mantra of "reuse, recycle and recover". The former practices are innovative, whereas the latter encompass practices that are already familiar and in common use.

From a social science perspective, these approaches are possible because a process of infrastructuring is underway. According to McFarlane and Silver (2017), infrastructuring refers to a practice of connecting people and things in socio-material relationships that underpin urban life. In the case of excavation spoil, this concept enables us to understand how regulatory changes, organisational processes and territorial dynamics interconnect, with varying degrees of friction and visibility.

Is the reuse of excavation spoil an innovation?

In public rhetoric, the idea of reusing excavation spoil as building materials stresses the novelty of the approach and the fact that it fits in perfectly with today's ecological transition agendas. It is associated with the emergence of a more endogenous form of urban development that consumes fewer external resources, making it more sustainable and hence less damaging to the environment, and which also encourages greater economy and frugality in energy consumption and cuts in polluting emissions. The vocabulary specific to industrial innovation (experimentation, eco-technological solutions) is extensively used.

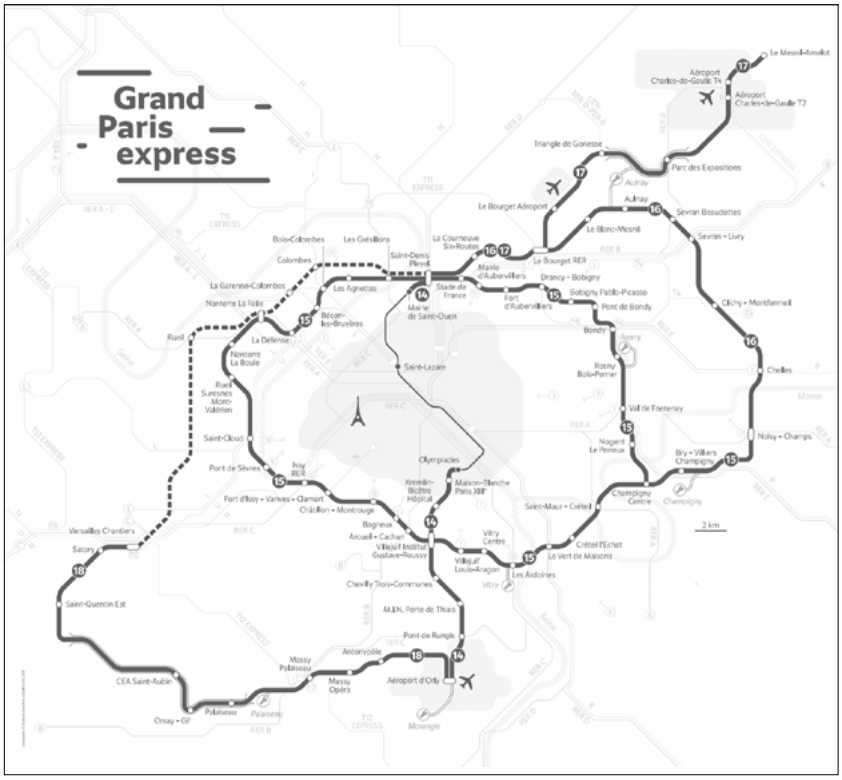
Can the experiments underway in the Greater Paris project be described as innovation niches? To answer this question, we first need to re-situate this study within the literature on sociotechnical transition pathways. Geels and Schot (2007) point out that changes in sociotechnical systems involve far-reaching reorganisations of technologies, supply chains, infrastructures, markets, regulations, usage practices and cultural meanings, all of which cannot be tackled without adopting a multi-level perspective. These changes occur mainly through interactions operating simultaneously at three levels. At the level of the sociotechnical regime, existing systems are maintained, protected and progressively improved by the actors in place, who are guided by deep-rooted rules and institutions. At the niche level, certain innovations emerge in response to new problems around which networks of actors propose solutions (or niche innovations) that challenge and disrupt the existing sociotechnical regime. Savini and Bertolini, specialists in transport and, in particular, in railway stations (2019), show that niche innovations come to the fore when certain events occur that can facilitate transitions by destabilising the existing regimes and creating windows of opportunity for such innovations. These two researchers theorise about the implementation of niche policies that support such experiments. These policies entail the creation, selection and conservation of emerging practices within an established institutional order. Not all these innovation niches have successful outcomes: some may lead to the extinction or marginalisation of the innovation, others to the assimilation of forms of innovation by the regime and the emergence of a new sociotechnical landscape

How do strategies for re-using excavation spoil emerge?

Limits to conventional methods of storing excavation spoil

I conducted empirical research through semi-structured interviews with stakeholders, participant observation at meetings where research relating to the Grand Paris Express project was presented and discussed, and analysis of operations carried out in the context of the Cycle Terre demonstrator. The research work was attached to a major organisation, Société du Grand Paris, which was created by the Act of 3 June 2010 as a public industrial and commercial establishment tasked by the state with the role of building more than 200 kilometres of metro lines (Figure 1) as well as developing property around the stations that will serve these lines between 2024 and 2050. Société du Grand Paris developed a picture of metropolitan development and looked for synergies with local authorities in order to embed each station in its local environment.

Société du Grand Paris faced increasing opposition over the issue of excavation spoil, which – according to Augiseau and Barles (2017)



1. The route of the Grand Paris Express metro network

Source : Grand Paris Express (www.grandparisexpress.fr).

– accounted for the second highest tonnage of materials entering urban environments.

The company planned to backfill around 400 quarries around Paris with these materials. One of the best known, in the Montmorency massif in the Val d'Oise, is mined by a Saint-Gobain subsidiary to extract gypsum and produce the famous plasterboard partitions. The company employs over 1,200 people and generates sales of around 500 million euros. The synergies are clear: the excavation spoil reinforces the galleries and prevents subsidence and ground movement on the surface. In 2017, this exchange of good practices was sealed by an agreement. Since then, 300,000 cubic metres of spoil from the construction of lines 15, 16 and 17 of the Grand Paris Express have been added to this quarry (Cognasse, 2022).

However, this win-win model has its limitations. In the Paris region, vacant land is becoming increasingly scarce and existing outlets, quarries and storage facilities are reaching saturation point. Local councillors in a number of départements on the outskirts of Paris are voicing their constituents' protests about the problems caused by lorries transporting these materials from the Greater Paris stations: material falls off the lorries and covers houses in dirt, drops onto the roads making them slippery in wet weather, and piles up in mounds, completely changing the landscape of the Greater Paris region and disrupting water circulation. In addition, local communities are concerned about the pollutants that may be uncovered by these excavations and their potential health effects (Collet, 2021). The fact is that recycling these materials would prevent such complaints. As a result, the issue of recycling excavation spoil as a construction material is becoming increasingly important, as is the search for new processes. What is being done to achieve this goal?

Innovation niches emerge between knowledge and know-how

Infrastructuring first and foremost means putting new ways of grasping realities into circulation, setting up questions as open problems and shaping communities that share a vocabulary and particular ways of thinking and imagining. What do the soil and subsoil of Paris Region look like? What are the precise names of the materials (limestone, marl, etc.) dug up from the sites? What are their physical characteristics, qualities and defects (strength, contamination, etc.)? The core samples taken for the construction of the metro made a major contribution to our knowledge and understanding of the region's geology. We now have data on soil structure down to a depth of 110 metres. Physico-chemical tests carried out at the base of the heap and in the laboratory were used to arrive at a detailed description of the granulometric composition, chemical components (particularly clays), pollutants (less than 5% of the soil is polluted) and mechanical properties of each zone. This has made it possible to determine the reuse potential

of these materials through a combination of two approaches. One is the technical characterisation of the material (its mechanical and sanitary suitability in its current state for a future range of uses), the other is the legal and economic analysis of the materials: what standards must be met for it to become part of a processing or storage programme?

There is a continuum between this specialised research and efforts to communicate and raise awareness within an ever-expanding circle of stakeholders in order to create customers for these substances and thereby convert them from waste materials into partly marketable products. Until now, the flows of materials entering and leaving the Grand Paris Express station sites have been invisible or largely unobserved. Giving them visibility is therefore the first stage in an integrated strategy to showcase the processed materials (aggregate samples, condensate bricks) and to prompt potential partners to imagine and visualise these colossal volumes (the equivalent of 70 Olympic swimming pools) and their potential capacity for reuse. With this in mind, in 2017, Joly&Loiret staged the "Terres de Paris, from stuff to material" exhibition at the Pavillon de l'Arsenal. Much more than a cultural event, the exhibition was the starting point for a number of experiments in reusing excavated earth as a building material. It demonstrated the possibility of manipulating twelve samples of excavation spoil and proved the capacity of certain bold architects to incorporate them into new buildings. The exhibition represented a tipping point, encouraging visitors to think of clay not just as a developing world building material, but as an "urban, ecological, social and contemporary" material (Loiret 2021).

Subsequently, conferences, exhibitions and publications on the virtues of building with earth proliferated, showing that fashion effects exist in research as well as in innovation. A whole series of events were staged to attract the educational, scientific and engineering communities, culminating in the "Terres et sol" (land and soil) architecture and landscape biennial in 2022, which showcased a number of earthen architecture projects using construction site spoil. On the cultural front, filmmakers and photographers (on commission) also shaped the public imagination. The author Jacques Jouet, for example, wrote ironically about the new mountains growing in Seine-et-Marne (Jouet 2022). This media coverage through exhibitions and publications is one example of the effort to break away from the niche position associated with the early experiments.

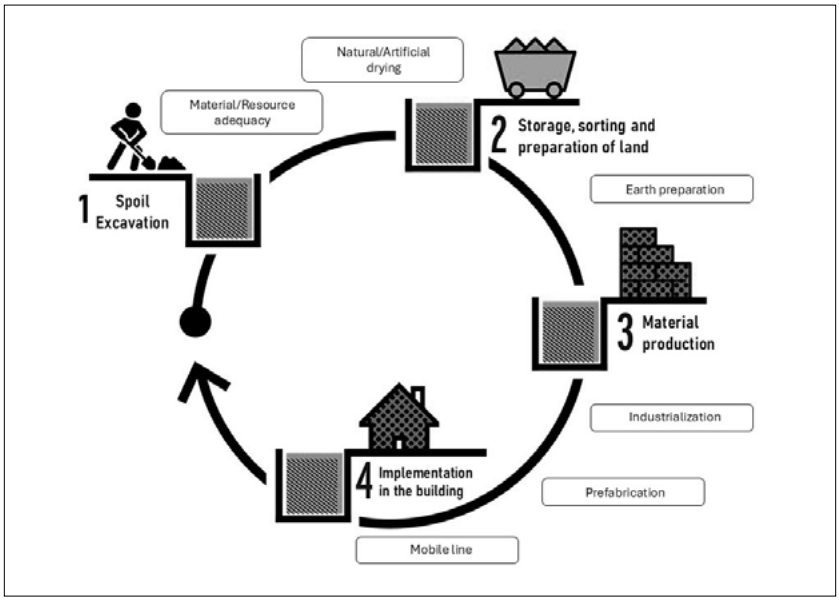
The key industrial demonstrator phase

While the Terres de Paris exhibition-experiment demonstrated that it is both conceivable and possible to make use of the rubble excavated from urban construction sites, it also raised questions about how to scale up

these processes. How can these recycling practices be industrialised and become part of a viable business model?

Cycle terre was born out of this question. This ecological demonstrator, supported by the municipality of Sevran and partly financed by European funds, was launched at the end of 2021 with a number of objectives: to start a production line for building materials made from excavation spoil, to create technical certifications, to initiate a development process with developers and architects, to involve local residents in projects and train some of them to work for local construction firms, and to spread to other European towns. Since then, three production lines have been developed and have obtained French certification, confirming the environmental virtues of this material: inertia and hygrothermal regulation, no negative health impact and no volatile organic compounds. Among the new products brought to market are raw earth bricks, obtained by compressing excavated earth and used for load-bearing walls up to two storeys – ground and first floor – in height (as well as for filling frames and internal partitions), clay panels created by extrusion (for partitions and non-load-bearing walls) and mortars and renders for masonry (Figure 2).

Cycle terre has therefore contributed both to the management regime for construction waste and to the construction industry. The demonstrator reinforces expertise and certifies its outputs, but remains fairly experimental, with very limited funds, space and manpower. According to its director, while demand is growing (interviews conducted by the author in February and September 2022), the same cannot be said about the scale of



2. Cycle Terre experiment

Source : author, no further use allowed)

industrial production. However, a first step has been taken with the creation of a showcase construction site. Located close by, the Sevran Terre d'Avenir ZAC (targeted development zone) aims to absorb 16% of the materials produced by the demonstrator, cutting the use of concrete in the construction of buildings from 94% to 70%. Raw earth bricks, clay panels and mortars are being used in combination with more standard materials.

Potential and barriers to escaping the innovation niche

Société du Grand Paris in search of a partnership framework

The building of the Grand Paris metro represents a unique opportunity to make use of considerable quantities of excavated soil and rock and to create a new market. The objective of Société du Grand Paris is to recycle 70% of the 47 million tonnes of excavation spoil, divided as follows: 45% for reuse on Grand Paris Express construction sites, 25% for landscaping, 20% for quarry infill and 2.2% for the production of building materials. This means organising the working environment and instituting rules and standards that influence the behaviour of a host of stakeholders operating in multiple sectors. The company created an internal department dedicated to the circular economy and excavation spoil, and is recruiting new staff with job titles such as "excavation and groundwork manager".

In addition, the company enlisted external expertise. The "Le Grand Paris des déblais" (Greater Paris Earthworks) call for tenders in 2017 initiated several doctoral research projects to characterise material excavated by tunnel boring machines in order to make it easier to trace, to test alternative – notably rail-based – transport systems, and to invent, test and certify new construction materials, as in the case of the demonstrator. For the company, the aim is to keep control of the innovation process and to orchestrate all the different parties involved, from upstream research to the recycling of excavation spoil, as summarised in Table 1.

Professionals involved in the "Grand Paris des Déblais"

	Laureates	Process	Contribution / Product	Location
Characterization / Extraction	" Diagnose Express ", NGE and Guintoli subsidiary *NGE is a French construction group, while Guintoli serves as its subsidiary specializing in roadworks and various networks (VRD) as well as earthworks.*	Enables reliable assessment of the risks associated with the presence of pollutants. Big Data analysis technology that allows for the prediction of pollutant elements prior to excavation, along with in situ analysis.	Anticipation of pollutant presence. Reduction in the duration of material characterization. Enhancement of spoil management.	Saint-Étienne-du-Grès (13)
Transportation	"Logistics plan for the evacuation of rubble from Greater Paris by train", Cemex and Innofreight	Use of waterproof wagons and patented box turning system to optimize rail flows.	Diversification of modes of transport. Transport of different debris by wagons and taking advantage of the return flow.	Cemex: 9 ports and 20 production units in Paris region (IDF) Innofreight
Road development utilizing geo-sourced materials	" ProVaDBat ", Séché Eco-Services and Hoffmann JB Technologies	Revaluation of spoil into construction materials: characterization phase of the spoil to recycle it and direct it to places of reuse.	Construction materials (parking, road sub-bases, street furniture).	Séché: 9 agencies in Paris region (IDF)
Revaluation - Landscape and soils	" TerraGenese ", Valorhiz	Creation of fertile soil from waste material and organic raw materials.	Fertile land.	Outside Paris region (IDF), Montpellier region
Revaluation - Geo-sourced construction	" Du déblai à la brique de terre crue ", Joly&Loiret (architecture agency), Dewulf (brockworks) and amàco (" raw earth " training center)	Transformation of construction site debris into raw earth bricks for construction.	Raw earth. Earth mortar panels.	Joly&Loiret, Paris Dewulf (Belgium, The Netherlands) Amàco, Villefontaine (38)
Revaluation – Stabilization of quarries	" SOLPUR ", Terbis and ETPO	Excavation to reinforce underground cavities.	Securing old underground quarries.	–

Source : Professionals involved in the Grand Paris des déblais call for projects (2022) (167797-qwd0fd75eb.pdf (grandparisexpress.fr).

Creation of raw earth construction sectors: Technical and legal difficulties

At present, Société du Grand Paris manages to recycle just under half of the materials, while the remainder goes into storage until recycling processes and a real market develop. The proportion of excavation spoil that becomes construction materials accounts for just 0.02% – one hundredth – of the stated target of 2%. A number of constraints stand in the way of achieving that target.

The first is technical. The conditions under which spoil is produced by tunnel boring machines on the sites of the Grand Paris stations mean that different types of geological composition are mixed together. This happens when the TBM's cutting wheel drills several seams at once. Mixed spoil is difficult to sort and the recovery process is severely compromised. Subsequently, the logistical process for storing and transporting it to one of the 400 outlets approved by Société du Grand Paris is also a risky phase, during which errors can occur. At the ECT storage site in Seine-et-Marne, for example, iron sulphides were found in the excavated and stored materials. When exposed to moist air, pyrite reacts with oxygen and water to form iron sulphide (rust), highly corrosive sulphuric acid and sulphur dioxide, a dangerous gas . For its part, excavation spoil that is contaminated with traces of hydrocarbons is handled separately, which means that several hundred lorries have to make an additional round trip across the region, slowing down the recycling process and requiring new players to join this long processing chain.

The second constraint is law-related and concerns the need for changes in legislation simply to legalise the process. As Garcier (2017) points out, construction and demolition waste account for two to three times the quantities of household waste, but receive relatively little political attention from urban authorities. Administrative interest in these issues is a recent development (Vega 2020). A law passed in 2014 classifies any earth moved from its original site as waste, and this complicates the processes needed to engage the sector in recovery activities.

Things are changing on two levels: law and certification. Firstly, an order published on 27 June 2021 sets out the criteria that must be met by excavation spoil and sediments that have been prepared for use in civil engineering or landscaping in order to be excluded from the waste category. The Anti-Waste Act of 2020 and its "Waste Traceability" order and the ordinances of 2021 and 2022 on the "Status of Existing Waste" govern the transfer of spoil from worksite to worksite, enabling contractors to ensure that soil has been treated for use in accordance with their quality requirements (Boissard et al., 2023). Secondly, ATEX (experimental technical assessment) certificates have been created, a joint initiative between a public entity, CSTB (Centre Supérieur des Techniques du Bâtiment – advanced

building techniques centre), and private actors in the construction industry. This technical assessment procedure applies to all innovative products and processes and is based on initial feedback before a technical ruling is issued. All three of Cycle Terre's products have received Type 1 ATEX certificates, whereas all the ATEX certificates previously obtained for raw earth construction were Type B (Luquain 2021). This is helping to bring projects to fruition: several school complexes in the Paris region (Figure 3), a day centre, and even a 42 unit housing development planned for Bagneux (Hauts-de-Seine). Does this really mark the end of this marginal status and the advent of circular urbanism as part of a local economy?

Innovation cannot overturn the dominant regime for handling excavation spoil

The vision of earth as a building resource is mostly found within the community of specialists and experts. It is not accepted in the institutional sphere (potential clients, e.g. public bodies) or in the operational sector (real estate developers).

On the institutional side, Bastin (2022) claims that the issue of construction spoil remains confined within a circle of administrative bodies specialising on questions of waste. Statistical tools are the responsibility of the Île-de-France Regional Waste Observatory (Ordif). Its focus is on frameworks where the issues are much more environmental than economic (preventing pollution risks, monitoring the sometimes criminal behaviour of certain companies (Institut Paris Région and Ordif 2019), etc.. The public authorities are primarily concerned with overseeing the conditions under which these materials circulate, not with developing knowledge

3. The Hauts du Moulin school complex in Villepreux (Yvelines), built using raw earth and timber frames.

and supporting new economic sectors. For their part, the actors that can support innovation in architecture and construction are sharply separated, culturally and relationally, from the environmental waste control networks. Excavated spoil from the Greater Paris metro accordingly suffers from this silo approach to public policy as well as from the power of the existing economic players (e.g. trucking and storage companies). The latter retain their power to prevent the small circle of visionaries that the Greater Paris company maintains (out of principle or as a showcase?) from breaking out of their niche.

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Although they attract a certain amount of media coverage, and although infrastructure is being put in place and the regulatory framework is gradually evolving to facilitate learning and experimentation, innovative processes for reusing excavation spoil as a construction material are still in their infancy. The procedures continue to be presented as experiments, applauded on a case-by-case basis but not deployed or adequately supported by the state, local authorities, businesses and the design professions. The projects that do exist are the exception that proves an obvious fact (that it is possible to build with this type of material) without leading to a situation where these isolated cases are integrated into the dominant regime.

Under these circumstances, could raising public awareness play a role? Already, in architecture schools, interest in raw earth construction is growing, with hundreds of students devoting their final degree projects to it in France and beyond. But instruction about the valuable properties of construction site waste is still struggling to find its way into course syllabuses. One way forward might be to look to artists such as Antoine Grumbach, who created a land art installation called Les Yeux du Ciel (ECT 2023) at Villeneuve-sous-Dammartin, on top of a pile of rubble from the Grand Paris stations. Only passengers on flights departing from nearby Roissy Charles de Gaulle airport can admire it, so few can get a chance to see what these materials excavated from the bowels of the earth and now looking back at us are trying to say.

Metabolic flows and station system functionalities: between ideology and experiment

Nils Le Bot

Over the past fifteen years or so, the anthropogenic nature of ecosystem disruption has come to the forefront of debates on architecture, urbanism and spatial planning (Derickson, 2018; Bulkeley, 2021). As an urban object that is addressed across multiple disciplines and on multiple scales, the railway station is today facing re-examination by researchers and practitioners from a new angle, in terms of its integration not just into the environment but into ecosystems.

In a departure from the 'sustainable development' and 'smart' approaches that previously prevailed, for several years now rail operators have been proposing new prototype stations that claim to demonstrate an ecological dimension, with figures and slogans to back them up. Combining considerations of energy, environmental impact – particularly on water and biodiversity – and materials life cycles, they form part of the emerging Railway Ecology debate theorised by Borda-de-Água et al. (2017) around the environmental impact of linear transport infrastructures.

The ecological footprint of stations

Stations, and the rail system to which they provide access, are today perceived as sustainable and desirable amenities for our societies as they enter a phase of transition (energy, post-carbon, ecological...). But these infrastructures have their roots in a triple legacy that has yet to be resolved.

– Linked to the intense use of carbon energy, which has left its mark on their architecture, railway stations are a product of the Industrial Revolution. This modern monster (Bony et al., 2020), represents a "capitalocene" legacy that has left a deep mark on landscapes, ecosystems and the climate, and has created a moral debt. Today, this forces railway operators to reconsider each station project from a perspective of frugality,

material optimisation and environmental mitigation (Ménard, 2021), but also with a view to containing certain societal resistances (Volin, 2020).

– The station is also a spatial legacy. It enjoys a sort of land rent in the city. A technical object situated at the threshold of pre-industrial urban space, answerable to topographical and cost rationalisation imperatives, its location was most often alien to the territories it passed through. In the twentieth century, railway stations became either isolated enclaves within cities or industrial wastelands in the heart of villages. They require appropriate governance at multiple scales, making them a terrain for experiments (Baron and Roseau, 2016). This privileged but criticised position requires railway operators to think beyond the mobility function alone, and to consider the civilisational role of stations (Bàn, 2008).
– Finally, the station is a place through which everything flows (goods, information, people). For a long time, its role as a nodal point (or hub) made it unconscious of or indifferent to the flows within it; its function was there simply to connect, but not to enter into a relationship with those flows. The approach changed with the emergence of the concepts of place-movement (lieux-mouvement) and of the station as node and place (Bertolini, 1998).

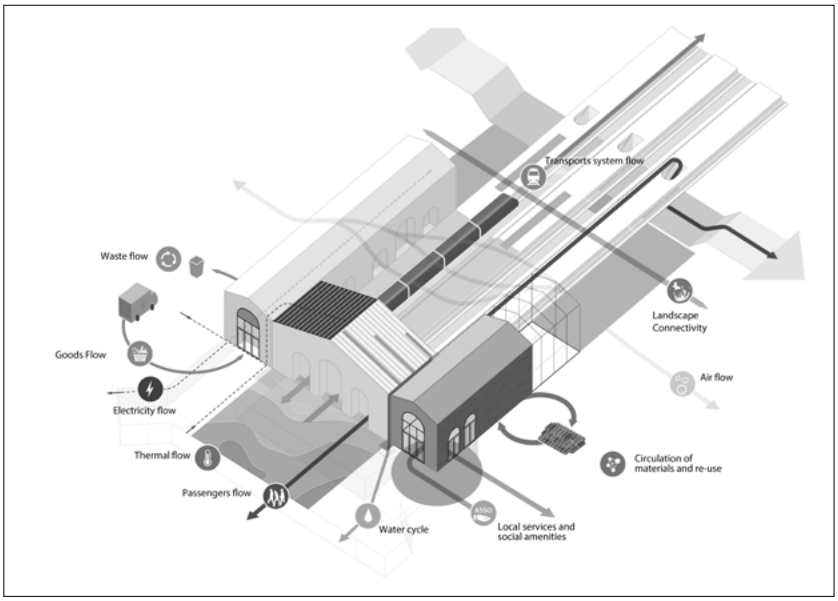
This triple legacy is now being called into question for reasons of sustainability:

– the ecological transition is limited by shortages of raw materials, technological inflation and its rebound effects (Bihouix, 2014);
– a partially dismantled public rail service is facing a loss of momentum needed to meet the expectations of a fragmented society and regions;
– it faces the prospect of a faltering European economic model, unsuited to a world of degrowth (in energy, the economy, mobility, etc.), whether desired or not.

A broader, systemic vision of metabolic flows

At a time when the globalisation-metropolisation binomial is in crisis due to its excesses (over-densification, concretisation, congestion...) and their vulnerabilities (climatic, sanitary and social), a new kind of language has entered the fields of architecture and railway design, based on new concepts of the city (circular, frugal, sober, inclusive, resilient, natural...). Aiming to combine resilience and frugality, these operational concepts take a much more integrated approach of stations and represent the return to a systemic vision (Cambien, 2008) at a time when circular economy principles are gaining visibility. In France, this situation has turned the spotlight on the concept of urban metabolism (Barles, 2008; 2017).

In this metabolic approach, the impact of the station's activities on the environment is assessed as a set of ecosystem relationships mediated by



1. Schematic of the main metabolic flows in stations

@ N. Le Bot.

flows of materials and energy. So, the question is whether the station can move beyond its transport function to provide ecosystem services as well as acting as a hub for metabolic flows on a regional scale?

Methodology

– We conducted a comparative analysis of station projects, concepts or prototypes built between 2008 and 2022 by the world's major railway companies, described by them as "exemplary" in terms of their environmental qualities and confirmed as such by a professional source (Rail Delivery Group 2021). We selected 25 stations presented by the operators in 11 countries: SNCF (France), DB (Germany), SNCB (Belgium), OBB (Austria), CFF (Switzerland), RFI (Italy), Network Rail (UK), ADIF (Spain), JR East (Japan), Pro Rail (Netherlands) and Indian Railways (India).
– For each case, we carried out a qualitative analysis of their environmental ambitions (expressed in writing or images, in corporate communications, press articles, etc.), which we classified according to their issues: morphology; production and use of energy; materials; water and air; measures to promote biodiversity; waste management; and the relationship with any existing built heritage.
– Through this review, we were able to:

– identify the main categories of pro-ecology architectural interventions proposed by the infrastructure operators;
– establish, through comparison and analysis, a gradation of the goals pursued with regard to the issues raised;
– characterise the level of ambition to which our conceptual proposal for a metabolic station could aspire.

Form: in morphological terms, these recent prototypes (passenger buildings, footbridges, platform shelters and other architectural elements) can be classified into three main families: standard buildings, which are conventional in their construction methods and dimensions; minimalist buildings, where the aim is to minimise the environmental impact through the frugality of the methods employed (reduced monumentality, smaller footprint, use of lightweight structures, etc.); and finally buildings with more systemic aspirations, which aim to achieve economies of scale through the use of modular and standardised architectural elements (as at Lutherstadt Wittenberg Bahnhof, [DB], Germany, or at Delft Campus [Pro Rail] Netherlands), or by the reuse of structural elements, as instanced by Barneveld Noord station (Pro Rail) Netherlands, built from reused containers.

Energy: Photovoltaic devices to limit the energy impact of stations are developing rapidly. Their visibility enables station operators to showcase their environmental investment. The panels cover roofs, shelters, glass surfaces and even some prototype benches. In the most ambitious approaches, the station's degree of energy self-sufficiency (expressed as a % or in days) becomes the indicator of environmental performance. This is the case at Hiraizumi Station (JR East), which comes close to 200 days of autonomy a year, or at London's Blackfriars Station (Thameslink / Network rail - United Kingdom), billed as "the world's largest solar bridge", though it supplies only 50% of the station's energy needs.

Material: Wood is the material most often touted for its environmental qualities. It is usually employed for cladding only, more rarely for structural purposes (Assen station, Pro Rail - Netherlands). In terms of provenance, several prototypes mention bio-sourced materials (Nîmes-Pont-du-Gard), local materials (Horrem, Germany), recycled materials (Delémont, Switzerland), and re-used materials (Yotsuya, Japan), although wood accounts for a small proportion of the total materials used, except in the case of the small rest area at Koria (Finland), which is almost 100% wood. Station design offices are developing skills in materials life cycle analysis in order to win environmental labels, such as the BREEAM label awarded to Solihull station (ARUP/ Network rail - UK).

Water: Mitigation of the impact of new station buildings on the water cycle is an aspect of almost all the cases studied. Rainwater is collected through the roof and used for station maintenance, servicing and watering

purposes (Lutherstadt Wittenberg, Germany, Rixensart, Belgium). Retention tanks for run-off water are built (Nîmes-Pont-du-Gard) or forecourts and car parks re-covered for improved drainage (Delémont, Switzerland). More rarely, wetlands have been restored (Assen, Netherlands) to protect against the risk of flooding (Wernstein station, Austria).

Biodiversity: Measures to accommodate and permit the movement of non-human life forms are still very limited in the ecological station prototypes studied. A shortcut between biodiversity protection and ground greening is becoming the norm in environmental messaging. In most cases, the emphasis is placed on green roofs and façades and tree planting on forecourts or around stations. The most advanced approaches mention the restoration of environments (cf. water) and habitats (Solihull - Network rail - United Kingdom), to offset artificialisation. Wernstein station (Austria) stands out because the stream, which was cut off in the original construction of this railway station, was restored and rewilded during its recent modernisation.

Air: The impact of train stations on air quality can be divided into three main categories: pollution, CO_2 emissions and cooling. Overall, there is little mention of these issues in the group of stations studied. Only natural, non-mechanised ventilation seems to be of interest to station designers: it is used at Yotsuya Station (JR East-Japan) and at Nîmes-Pont-du-Gard. Still at the concept stage, the future Green Hubs on the Rete ferroviaria italiana plan to implement real-time air purification. Dutch company Pro Rail's Fully circular stations aim to implement CO_2 absorption measures

Waste: The issue of waste is still largely unaddressed in environmental innovation plans for stations. In an effort to reduce the impact of waste transport, construction waste was removed along the Thames at Blackfriars (Thameslink/Network Rail - United Kingdom).

Heritage: Although this aspect is not specifically cited by infrastructure operators as an environmental criterion, renovating an old station rather than building a new one (making do with what is already there) is a land-saving factor (Reike et al., 2022), There are three levels of intervention:

- re-used stations are stations where existing buildings and passenger areas are upgraded. Renovation represents a calculable saving in energy, materials and carbon equivalent;
- augmented stations are stations where technological systems are added to existing sites (for example, by the installation of photovoltaic equipment);
- new stations give designers more scope to respond to environmental challenges by experimenting with form, technology, etc.

An ideal-type ecological and metabolic station

A number of lessons can be drawn from this analysis.

First, while the new environmental aspirations of operators are now reflected in a common new vocabulary (CO_2, energy self-sufficiency, bio-sourced materials, biodiversity, etc.), their efforts generally focus only on certain themes; strictly speaking, there is still no demonstrator in which all these aspirations are combined in an integrated way.

Second, there is a kind of gradation in the environmental measures. The documents provided by the rail agencies range from simple references that assign a cosmetic role to the environment (e.g. different bins for different kinds of waste) to bigger ambitions and more methodical measures to reduce environmental impacts. Drawing inspiration from these more advanced examples, and setting the slider for the ecosystemic integration of these flows to its maximum level, we can sketch – as a speculative exercise – the outlines of an ideal-type of ecological and metabolic station. Such a station would seek to:

- no longer outsource wastewater handling, but instead contribute to the treatment and/or distribution of water in the surrounding area;
- regulate its air quality (temperature, humidity, pollution) and could go beyond passenger comfort alone (Baudoin et al., 2020) to provide a climatic (Ménard, 2021) and atmospheric refuge for its users (see Émile, chapter in this book);
- pursue a circular approach based on waste reuse and recovery. Since 2021, Indian Railways has been trying to put the zero-waste railway station concept into practice (Jain 2021), proposing the complete retention and recycling of all the waste produced by stations, in the form of materials for reuse or agricultural compost (Patil et al., 2014). In France, we can cite the reuse of excavation soil (El Cherkaoui Baraka, this book) and architectural materials (Detavernier and Striffling, this book);
- produce more energy than it consumes;
- become once again a place for growing food and micro-production, on the model of the prewar railway worker allotments (Stilgoe, 1982). This approach obviously raises issues of land availability, health and socio-economic value, given the strategic importance of land around stations;
- be more open to biodiversity (chapter by Auvray et al. in this book). The case of Wernstein station (Austria) shows that a form of coexistence could be reached with certain environments; the study of stations such as Kalamata in Greece (closed in 2010) or Khandala, in India, reveals the presence of many trees even on the platforms, which shows the capacity of stations to play a role in carbon capture and sequestration.

Summary of the main ecological functions associated with railway spaces

Gradation Indicators	Anthropization	Mitigation	Zero impact	Symbiosis / Impact +	Issues
Water	Captures water for locomotive operation	Recover and reuse rainwater for its operation	A station part of the water cycle. Closed-loop processing	Integrated wastewater treatment plant	Technical investment ratio and real eco-economic relevance.
Air	Steam emission, fumes, pollution due to braking, UHI	Particulate filter, demineralization of forecourts, air conditioning	Natural ventilation, zero pollutant emissions	The *train station is a climatic refuge*?	Mutation of heritage. Stationarity in the station.
Matter	Extraction and import of material to build and maintain stations	Use of bio-based materials, low-tech design	Reuse, Recycling and recovery within the closed-loop rail system	Material deposit Urban mine	Network-wide flow storage and management. Organizational, technical and normative challenge. Socio-economic relevance.
Rubbish	Export of waste	Waste management, sorting and reduction			
Energy	Imports fuel oil, coal, power plants	Partial production	Autonomous energy production on the railway territory.	Reinjection into the grid	Scale ratio between exportable energy and energy actually produced
Food	Food import	Honey production, small-scale rooftop farming...	Autonomous railway metabolism, self-sufficient railway system?	Agricultural stations	Relationship between land availability and socio-economic relevance. Health aspects.
Biodiversity	Land artificialisation, mineralisation of roads, relationship with living things	End of phytosanitary products. Revegetation. Preservation of natural environments	Circulation of living things	Biodiversity refuge	Cohabitation of living things with spaces with strong technical constraints
Carbon	GHG emissions	Low GHG Emission Building	Zero GHG Emissions Building	GHG capture and sequestration infrastructure	Scale ratio between GHGs emitted and GHGs actually captured

Limitations of current experiments: the case of Nîmes Pont-du-Gard

To understand the challenges and limitations of this metabolic approach to stations, we studied the case of Nîmes Pont-du-Gard and the gap between ambitions and current reality there in more detail.

In 2019, SNCF Gare & Connexions opened Nîmes Pont-du-Gard, a station designed to accommodate 400,000 passengers a year, with clearly stated ecological ambitions. The station is located in the municipality of

Manduel, at the intersection of a TER (regional express) line (Tarascon-Sète-Ville) and the new Les Angles-Lattes high-speed line. It is built amid fields and partly in a "Natura 2000" classified zone, in an area exposed to earthquake and fire risk.[21] It covers an area of 26 hectares, including a future theme park and a 140-hectare business park called Magna Porta. Even before the station was delivered, the ZAC (special planning zone) project had been criticised on economic[22] and environmental grounds, and was the target of legal proceedings,[23] despite being certified to environmental standard ISO 14001. As of 2023, the ZAC is stalled between legal requirements for environmental offered and the area's evident lack of economic attractiveness[24]

It is in these conditions of tension, where environmental performance is simultaneously a technical, legal and political issue, that the architecture and engineering firm AREP is designing a 4,400 m² passenger building that is to play host to a wide range of experiments rooted in Building Information Modelling. IT tools can be used to optimise the use of bio-sourced materials, to attain a 100% rainwater infiltration rate and to recycle excavated soil. With regard to the highly sensitive issue of tree felling and landscape integration, 223 of the 435 trees on the site have been preserved and 390 new trees planted. Of the 26 hectares of exterior landscaping, 5 ha are being replanted under the supervision of an ecologist. The car parks, equipped with 7,700 m² of photovoltaic sunshades, produce 4 times the station's electricity needs. While the construction process emitted 15,000 tonnes of greenhouse gas equivalent (tCO2e), almost 5,000 tCO2e of emissions were avoided during the first two years of operation thanks to solar energy production.

A number of lessons can be learned from this case study.

As a territorial project: a station project, however ecological, remains first and foremost an infrastructure project for the parties involved, in a region of France where local authorities have well-established land use and artificialisation practices. The ZAC project demonstrates the importance of this link between the station and economic and regional development and its destructive effects on the environment.

With respect to uses: while there are photovoltaic roofing systems, they exist primarily to cover 1,000 parking spaces. Similarly, 77% of the project ground surface is sealed for functional reasons (access, passenger movements, logistics, etc.). Under these conditions, Nîmes-Pont du Gard station

21. https://www.midilibre.fr/2022/07/26/un-incendie-en-cours-a-manduel-perturbe-la-circulation-entre-nimes-et-beaucaire-10457259.php
22. https://www.midilibre.fr/2018/03/02/magna-porta-les-riverains-inquiets,1634517.php
23. https://www.midilibre.fr/2019/03/06/nimes-les-recours-contre-la-gare-de-manduel-rejetes,8052987.php
4. https://www.objectifgard.com/politique/expresso-nouvelle-strategie-pour-le-developpement-de-magna-porta-106068.php

2. Location and facilities at Nîmes Pont-du-Gard station

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is well suited to a rural area of southern France that is highly car dependent and enjoys a lifestyle that is not very energy-efficient.

On a technical level: two years after the handover, the value of the technical innovations has been assessed (AREP 2020). The laudable attempt to reuse soil from the site to make concrete has run up against regulatory barriers. The adaptation of the greenery and the return of certain species of fauna (chickadees) have come at the price of significant additional costs in the upkeep of the planted areas.

All this shows, on the one hand, the technical limitations of prototype stations and, on the other, the inertia of station production methods, whose wider ecological effects on the area (for example, the car traffic they generate when they lack public transport access are not accessible by public transport) are certainly greater than their actual ecological benefits. We can therefore see that the advent of ecological and metabolic station models requires planning specialists to become acculturated, well beyond the professional circles of station designers and managers whose action is embedded in new socio-economic realities.

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This chapter has sought to explore the emerging field of railway ecology and is intended as an invitation to "develop an infrastructural narrative commensurate with environmental realities and conditions of habitability" in order to "breathe new life into the unfulfilled potential" of infrastructure (Roseau, 2022).

We explored the relevance and priorities of an ecological and metabolic approach to the design of railway stations. While none of the cases studied has yet developed an integrated vision of all these issues, a change in practices is clearly underway among station designers. However, if the local socio-ecosystemic realities specific to each network point are taken into account, the pursuit of these metabolic aspirations will inevitably have to include relations of cooperation and interdependence (between stations, with the station and its urban, rural and natural context, etc.) if we hope to get closer to this ideal and this ideal-type.

Taking these flows into account, even partially, would mean redefining the function, typology and culture of the station as an object. Ecodesign is still too simplistic in its approach to the complexity of ecosystem interactions. It remains rooted in a highly technical perception of how to regulate material and energy flows. Circularising the metabolic flows of the station system (Le Bot 2021) can only be a theoretical model for the time being, as its realisation requires political conditions, in the noble sense of the term, to ensure the cohabitation of socio-technical systems and the biosphere.

Part 3.

Atmosphere and Landscape

The mistuned station: soundscapes, public spaces and marginal (im)mobilities

Thibault Carcano

Tired of the noise coming from the alleys of his upscale housing lot, an American graphic designer developed a small box that emits a shrill sound that only teenagers and young adults can hear. Powerless in the face of this sonic arsenal, the kids abandoned the public spaces and the housing lot became quiet again. Marketed in 2010 under the name Mosquito, the device initially enjoyed resounding commercial and media success. However, a chorus of voices joined together in condemning the violence of the device, to the point that, a few months after it went on sale, the Council of Europe ruled that the Mosquito violated the principles of respect for physical integrity and freedom of peaceful assembly. Following this ruling, a number of towns and cities passed legislation to ban the device, but there is still no national law governing its use. In the United States, for example, a handful of rail operators – notably in Hamilton, Helensburgh, Washington DC and Philadelphia – relied for a time on this solution to prevent young people from hanging out in their premises, as they were deemed to undermine the smooth running of the stations.

Although anecdotal, the use of this instrument does demonstrate the importance of issues around the production or experience of noise on public transport. From the 1980s onwards, the term "soundscape" (Southworth, 1969) became popular in the French academic community, at CRESSON (the sound space and urban environment research centre) and Ircam (acoustic/musical research and coordination institute). It is a term that refers to wide-ranging research into the sensory, subjective and contextually relative impressions produced by architectural and urban design, and especially by the design of transport facilities.

The station, as a distinct and protean place – or heterotopia (Le Bot, 2019) – produces a unique soundscape. The aim of this chapter is to show how a sound-based approach to railway stations provides new insight and, conversely, how the case of railway stations bears witness to the importance of soundscapes in the urban and railway fabric. It also implicitly provides matter for consideration about the shared (if not public) nature of station space-time (Chelkoff, 1992; Amphoux, 2003; Tardieu, 2006).

This research is based on a mixed protocol: a transdisciplinary literature review; an ethnographic and sensory survey conducted at Paris Saint-Lazare station; interviews with experts and operators of transit spaces. The contrast between what was said in the interviews and what was observed in the field reveals the discrepancies between the functions and uses of transit spaces.

I will begin by taking a long-term view, looking both to the past and the future (Part 1). I will then show that controlling soundscapes is a strategic priority for station managers (Part 2). Finally, I will explain how a sound-based approach helps us to understand social margins in a different way and, therefore, to think about the future of stations as urban spaces (Part 3).

Sound as an architectural terrain

Anthropo-history of sound

Sound is a paradoxical object within architectural practice: it is both a foundational problem and a perpetual afterthought (Spence, 2020). The builders of antiquity already had a solid grasp of acoustics, since they were able to build theatres in which everyone could hear the actors' words perfectly. However, it was not until the industrial revolution that the acoustic environment was recognised as a crucial factor in landscape quality (Chelkoff, 1992). And it was the discomfort caused by noise in the new industrial age that placed it on the agenda for public action, in a bid to combat the unbearable mechanical cacophony of the era (Geisler, 2008). According to Chételat (2009), this negative perception has conditioned the way it is treated to this day.

With the exception of rare and specific structures where acoustics play an essential role (for example, auditoriums or lecture halls), designers have essentially focused on controlling noise levels (i.e. the decibels emitted) rather than on generating pleasant acoustic environments. Despite an exponential increase in the quantities of data handled by designers (in the era of Big Data, Building Information Modelling and Geographic Information Systems), little attention is still paid to the sensory qualities – other than the visual aspects – of buildings and furnishings. This is because architecture's penchant for visual media and characteristics is just one of the consequences of the hegemony of the eye within our global system of interactions with the world.

Our inclination for sight has biological and societal foundations ([S]CITY et al., 2021; Volcler, 2014) but it is also a social construct. For example, some people develop extraordinary hearing capacities because they cannot rely on their eyesight. They translate sound signals into spatial information which becomes the basis of their proprioceptive responses (Rychtáriková et al., 2012). Conversely, people who are unable

to appreciate soundscapes take refuge in synthetic sound: in stations, one person in three disengages from reality by donning headphones or earphones (Volcler, 2017). The result is a gradual disappearance of the ability to listen to, understand and interpret soundscapes

A wide spectrum of station soundscapes

The many activities that are concentrated in stations (transport, shopping, meeting, waiting, etc.) create a complex and changing soundscape. Without attempting to cover the multitude of constitutive tones, they notably include voices (of passengers, members of staff or pre-recorded messages), alerts (beeps, sirens, bells, whistles, music) and acoustic externalities, most of which emanate from different forms of movement (footsteps, suitcase wheels, crossings) or are mechanical in origin (vending machines, escalators, train brakes, ventilation systems).

The mix of these signals varies across stations, depending on their geographical location, size or morphology. For example, Montparnasse and Saint-Lazare stations are similar in size and location, but differ…

– in their acoustic structure – among the notable differences, the platforms at Paris Montparnasse are situated under a slab, whereas those at Paris Saint-Lazare are covered by a canopy;
– in the nature of their users – traffic at Saint-Lazare station consists essentially of commuters travelling within the Île-de-France region, whereas traffic at Montparnasse station is geared towards the main-line routes (and the noise produced by high-speed train engines differs from the Régio 2N trains operating in suburban stations);
– in the importance attributed to acoustic design, which is much greater at Saint-Lazare than at Montparnasse.

Moreover, within the same station, the soundscape varies according to spatial and temporal factors. For example, in both winter and summer, the hum of air-conditioners is a major element of the soundscape in enclosed spaces (usually in waiting or shopping zones), but cannot be heard on the platforms or in the concourse (Tardieu, 2006). Similarly, escalators can only be heard from close by. Finally, in temporal terms, noise volumes are also highly time-dependent, if only because of the variations in passenger traffic that are a daily feature of stations.

Soundscape at the interface between technology and aesthetics

In technical terms, sound volumes depend more specifically on the absorption and reverberation characteristics of buildings. Acoustic designers for stations ensure that sound intensity levels are appropriate to the function assigned to the space (Tardieu, 2006). They keep the noise as low

as possible in waiting areas (so that announcements can be heard clearly) while tolerating – if not encouraging – a hubbub in the station concourse (to highlight their monumental aspect). Transitional spaces, such as corridors and passageways, on the other hand, receive little attention, as the average user does not spend much time in them.

Under normal operating conditions, the sound volumes measured in stations range from 45 dB(A) – a very low volume, equivalent to the sound of distant footsteps – to 75 dB(A) – a high volume, as found in the immediate proximity of a major noise source such as a train (as a general rule, an increase in sound level of 10 dB(A) doubles the perceived volume). Therefore, a sound in excess of 75 dB(A) – for example an alarm, a scream, a bang – alerts you to a malfunction in the station and, more broadly, to a potential danger (Cheverry and Regairaz, 2019).

Despite their complexity, users adapt, become accustomed and attached to soundscapes, to the point that certain elements – such as the much-missed paddle noticeboards and their characteristic *flipflap* – acquire heritage status. However, station operators are keen to keep their soundscapes up-to-date. Among the most notable initiatives, the Piano in Stations operation – launched in 2012 as part of the international Play Me I'm Yours artwork campaign initiated by Luke Jerram – gives stations a distinctive new musical touch (Rochefort and Lopez, 2022) and offers users an opportunity to express themselves melodically. More recently, within the context of its collaboration with FIAC Hors-les-Murs 2015, SNCF hosted a series of performances in which sound was used to to highlight particular features of stations such as the nave (Laurent Durupt, Paris Est), as well as people and pigeons (Robin Meier, Paris Austerlitz).

Creating soundscapes as a management strategy

A tool for orchestrating passenger flows

Sound is an essential medium of passenger information (in conjunction with visual signage, maps, remote displays, station staff and real-time digital information). Like visual signage, it is present throughout the user's journey, from the moment they enter the station to the moment they leave (Bayart, 1996). Although visual signage is still more widely used than its aural counterpart, the two are nevertheless complementary. The presence of both ensures that information is transmitted securely and that users can assimilate it even if one of their sensory inputs is blocked (for example, when visual signage is obscured by a crowd). Moreover, audible signage is by its nature temporary, so its advantage is that its use

1. FIAC 2015: Score for 12 pigeons and three musicians at Austerlitz station.

Avec l'aimable autorisation de Robin Meier.

Interview with musician and performer Robin Meier

In 2004, as part of a Parisian White Night, I had the amazing opportunity to work with Frédéric Voisin on the marquises, the monumental metal lacework that covers the long tracks of the Gare de l'Est. The idea was to take advantage of the existence of this 3D space in stations, which is so rare in the contemporary city, in order to experiment with the spatialisation of sound, in other words, to research the possibilities of capturing and transposing the magical atmosphere of stations into musical form. In order to reshape the sounds of the station, to organise and broadcast them, I installed a system of loudspeakers and projectors and was able to compose music not by means of directly executed commands, but indirectly, using signs and indications of the station ambience based on minute and permanent variations in its light intensity and tonality. I've never ceased to be attracted to stations, places that always evoke others, absent or imagined, through the magic of travel. For me, the imaginative potential of the station is very much linked to the reticular pattern, and to the properties of networks, whether rail, electrical or virtual, which are so closely linked with our contemporary condition as eternal migrants.

In fact, it was the most mobile – and at the same time most prosaic – animals, a permanent but almost unnoticed presence in railway stations, that I put at the centre of my last performance, at the International Contemporary Art Fair's Hors les murs event in 2015 (Figure 1). Pigeons are, after all, travellers themselves, and once again I wanted to work at

the frontiers of acoustic research, sound experimentation and musical creation. I started work on the project after spending many long days at Gare d'Austerlitz, soaking up the atmosphere of this station, the only one in Paris without a TGV high-speed train, and one which still has a very particular sound signature, perhaps a little retro, with the din of the locomotives turning up the power, the hubbub of the morning stream of passengers, the clamour of the cars in the adjacent avenues... but also moments of almost absolute calm in the middle of the day. I tried to link these multiple ambiences with the station's secret code, its graphs and schedules for managing the tracks, platforms and engineering works, to play on these alternations between silence and tumult. My vision as an artist is not to 'hide' the sound of the station, but on the contrary to take everything that is musical, and a little ghostly, hence the idea of the ghost traveller in the station's specific sound signature, and to complement it, harmonise it, with this winged ballet of pigeons fitted – in accordance with Chinese tradition – with a sound device when they take flight.

One of my greatest satisfactions is to have been able to capture, in the exchange of glances between dismounting passengers, the mix of surprise, then interrogation and finally interest in this performance. The pigeons were a big source of surprise, but so were the three instrumentalists on the platforms: people experienced and discovered the performance gradually, they first grasped what was happening, walked on, and suddenly became aware of the unity of the arrangement, its harmonies, the effects of call and response, thus seeing in a fresh or at least novel light the station that they have perhaps used every day, all their working lives, and that they no longer notice.

Interview with Robin Meier as part of the Quand la Culture s'invite en Gare conference 16 April 2016 (PUCA

can be adjusted to the circumstances. In the case of visual signage, this flexibility is only possible with digital technology.

On the other hand, audio signage does not have exclusive access to the soundscape. It can be disrupted by the use of personal audio devices (such as earbuds and headphones) as well as by the mass of unofficial sounds present in the space. The latter implicitly form a competing signage system, sometimes useful, sometimes a source of confusion (sound decoy effect). To overcome these limitations, transport facility operators are trying to reinvent the way they communicate through sound (Volcler, 2015).

One of the avenues being explored is the transition from one-time, verbal signage to diffuse, non-verbal signage. In the case of French stations, we don't find devices as extreme as the Mosquito, but in the 2010s several SNCF sites (Paris Nord, Paris Saint-Lazare, Paris Montparnasse, Angers Saint-Laud, Nancy-Ville, Valenciennes and Rennes) played continuous classical music to discourage so-called undesirable populations from lingering. In addition to these 'hostile design' measures, the development

of the cognitive sciences and, in particular, work on so-called nudge theory (methods used to guide individuals unconsciously towards adopting a purportedly beneficial behaviour) has also influenced thinking on station environments. Sound design can alter the way people feel and modulate their walking pace. For example, the *chime* that sounds when passengers swipe their Navigo Pass (the travel card used in the Île-de-France region) and, to a greater extent, the sound of the carriage exit alarms, prompt automatic acceleration, reducing the risk of congestion (Volcler, 2017).

Commercial leverage

In addition, soundscapes are created as an accompaniment to station transformation, particularly their conversion to retail spaces. Visual advertising media have long been present in the station environment (Detavernier, 2021); now sound is also seen as an instrument of profit generation. The shops in the station's retail spaces rely on selected music being played to attract customers, accelerate turnover and increase their conversion rate – the preferred musical style varies according to the product sold: jazz in cafés, pop in trendy clothes shops (Vocler, 2017) and a hushed silence in upmarket brand outlets.

In addition, the change in the sounds SNCF produces bears witness to the company's transformation from a state-owned organisation with a public service remit to a market-driven entity. In the 1940s, station announcements featured a multitude of accents and intonations, reflecting the variety of local dialects. Later, they were first replaced (in the 1980s) by the iconic voice of Simone Hérault and then by other railway workers' voices, now polished and expressing themselves in accordance with informational and syntactic codes predefined by the company. Similarly, the jingle that precedes announcements has undergone a symbolic transformation. The bell used in the 1940s was replaced by an electronic carillon in the 1990s, and since 2004 has adopted a variety of instrumental variations. The ergonomic efficiency of the first jingle, designed to operate in a varied range of environments, has therefore been replaced for the purpose of promoting the company through sound (Volcler, 2017).

This is a questionable choice in light of the need for soundscapes to be intelligible. Just as poster advertising undermines the effectiveness of visual signage (Detavernier, 2021), the use of sound messages for commercial ends short-circuits the transmission of practical information.

Marginality through the prism of sound

Towards a new definition

From the examples above, we can see that the purpose of greeting users with sound in stations is to achieve collective optimisation rather than to offer a personalised response, especially if the individual stands for the mass. However, each user perceives soundscapes in their own way, according to their social, physical and emotional characteristics ([S]CITY et al., 2021) as well as their priorities. Our noise tolerance differs depending on whether we are stationary or on the move, or are looking to shop, catch a train or eat.

So the soundscapes created by the rail authorities generate margins, in other words situations of marginalisation or exclusion. Depending on the populations for/against which they are conceived, they can be a source of…

– confusion, due to information deficiency or overload;
– incomprehension, for people who are unable to situate the sound signals within an intelligible system (Meissonier, 2016);
– hardship, for the users most sensitive to noise exposure (high sensitivity, long exposure, proximity to a noise source, etc.);
– stigmatisation, for people whose noise level clashes with the tacit norm of discretion that the station imposes on its users (Redier, 2019).

Ultimately, sound is a way to unite under the banner of marginality all the people who find themselves quantitatively or qualitatively limited in their use of the station because of the way they respond to or produce sound (Rychtáriková et al., 2012). By emphasising matters of use rather than individual characteristics, this method of definition helps us to avoid the pitfall of essentialising and stigmatising marginal individuals. As a result, such individuals are not assigned a status of absolute negativity (absence of physical, cognitive or economic resources) but rather a situation – i.e. the interaction of an individual state and a spatio-temporal context – that is relative and protean, hence lacking any associated value judgement.

An inclusive approach to sound in stations

The goal of this new definition of marginality is to conceive transport space not as a single environment for all users, but rather as a tangle of environments in which everyone can enjoy the same level of service, whatever their situation. In this respect, it echoes the ideal of "universal design" developed in the 1970s to demand a production of space that is equitable, suited to the needs of each individual and open to unexpected behaviour (Audirac, 2008; Rychtáriková et al., 2012).

The underlying assumption is that an inclusive space – one that meets the needs of the most vulnerable – is also a hospitable space – one that is pleasant for all users. The proliferation of lifts and escalators in stations is a

textbook example: originally installed in response to repeated requests from wheelchair users, these devices are now used by almost everyone (Aubertel, 1999). Similarly, accommodating the needs of people who are sensitive to noise enables us to build a better transport service (better signage, development of upstream, real-time online information systems).

Moreover, noise disturbance is insidious: the average person may not perceive the full destructiveness of a degraded soundscape, but they nevertheless suffer from it – according to the World Health Organisation (2011), a million years of healthy life are lost every year in Europe due to noise pollution. This is why feedback from people who are most sensitive to the quality of soundscapes is a valuable resource in identifying noxious sounds and finding ways of correcting them that benefit everyone (Meissonier, 2016; [S]CITY et al., 2021).

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Listening brings to our attention information that complements the information that can be extracted from vision or any other sensory source. In this respect, it reveals otherwise imperceptible margins and vulnerabilities.

The soundscapes of stations echo the urban quality of the place. Monumental, intense and diverse, they reveal the socio-spatial paradox that stations embody through their status as ERP, public assembly buildings (article R. 143-2 of the French Construction and Housing Code), in other words, mass access private spaces. In addition, they bear witness to the crisis of urban quality that stations are experiencing, threatened by the advance of the commercial realm, the desire for control by authority figures and the retreat of users towards individualistic strategies.

To counter this trend, we need to rethink the mechanisms of spatio-temporal co-production by taking all users into account. It is not a matter of allowing some people to enjoy space and time without affecting the ability of others to do so – if that is even possible – but of designing places that maintain and encourage "sensitivity to the Other" (Amphoux, 2003), in short, spaces of harmony.

If stations are digital ecosystems, why can't lost luggage be found?

Arina Rezanova

One of the anxiety-inducing aspects of train travel is the fear of losing your luggage and personal belongings. This experience, which is both commonplace and frequent (more than 8,000 station police operations per year), is increasing in frequency (30% more objects lost in the last two years on the French rail network) (Poingt, 2021). It creates a twofold problem. For travellers, the loss causes stress (some have had their doctoral thesis stolen, others a Stradivarius). For station operators, it disrupts station operations, since such items are no longer handed in to lost property offices. The last ones closed after the 2015 terrorist attacks, and since then the response to the problem has come from the IT and security sectors, which have deployed a host of instruments like cameras and tracking applications to deal with it.

The change in the way the problem of lost property is managed is an instance of how big city stations can be viewed as sociotechnical constructs within which logistical – hence physical – flows (the movements of trains, pedestrians and countless bags, suitcases, etc.) and virtual information flows are connected. This allows us to explore these infrastructures as digital ecosystems and to try to understand the logic of production and the conditions of interaction with passengers.

Station digitisation combines virtual dynamics with very physical realities that can be explored in their new spatial organisation. Photograph 1, taken in the new Nîmes Pont du Gard TGV station (commissioned in 2020), shows a 35 square metre waiting room that contains a combination of comfortable furniture and a range of artefacts designed to engage passengers with what marketing specialists call omnichannel experiences mediated through a profusion of screens (Baron, 2022). This tells us that planners increasingly see stations as data havens underpinned by extremely costly physical instantiations that are not necessarily visible to the harassed traveller: electronic servers, fibre-optic cables, Bluetooth and 5G sensors, terminals, etc. And behind these are whole constellations of actors: the tech giants, start-ups, public and private players in the transport

and digital sectors, etc. Together, they form an ecosystem, defined as a dynamic assembly of humans and material and virtual objects, which all intersect in different ways to produce different realities and experiences: brand loyalty, efficient flow management, value through the capture of personal data, collective security ....

Returning to the issue of lost property, this chapter aims to answer the following question: why does the loss of passengers' personal belongings, which in theory offers very favourable prospects for the so-called

1. Connected space designed by the Canopée agency for Nîmes Pont du Gard TGV

Source : Gares & Connexions (no further use allowed)

MaaS (Mobility as a Service) market, linked as it is with the advent of surveillance technologies (Zuboff, 2019), remain a marginal element in the digital landscape of railway stations? To answer this question, we contacted the Connectivity and Innovation Unit at Gares&Connexions and produced a first-hand database of applications for managing lost property events. After clarifying the way in which the notion of the digital ecosystem applies to stations, in the second section we explore the functions of such digital applications before illustrating how they have so far failed to connect real and virtual mobility experiences and hence to promote effective digital use for the recovery of lost property

Theoretical framework

Stations as hybrid sociotechnical ecosystems

The sociotechnical approach offers a valuable theoretical prism through which to analyse the relationship between digital technologies and transport infrastructures (Graham and Marvin, 2001). It observes stations as assemblages that can be broken down into dyads: human and nonhuman, materiality and nonmaterial information flows, inanimate objects and artefacts that communicate (with humans and with each other through the Internet of Things), and also real and imagined nature. For example, the design of the waiting room at Nîmes station suggests a space formed of innovative and natural materials, and conceived as a sensory and allegorical instantiation of the territory.

> "Serpentine" is a synthesis of the different sensory components of the surrounding natural environment: the arabesques of the Gardon and the sedimentary red earth of the Costières. Between the architectural structure and the functionality of the seats, the "Serpentine's" sculptural and artistic approach complements the scenographic quality of the space. Digital signage systems display "seductive" video content about destinations" (Agence Canopée, 2022).

All these physical and digital arrangements require a significant layer of infrastructure and technology. The traveller has access to a very small part of it, the layer that is visible and showcased, while a second layer is more discreet (cameras) and a third is hidden (miles of cables and a host of electrical and electronic cabinets in partitions and false ceilings). Finally, a fourth part of the station's digital reality consists of a set of computer codes and moving data that is stored in servers and clouds located hundreds of kilometres away.

Railway station digitisation is not a recent phenomenon, and its promoters have been pursuing a line of approach that has not changed much in the last thirty years. In the age of artificial intelligence, big data is supposed to help operators to manage stations ever more safely, and to anticipate and optimise peaks in passenger numbers, such as those associated with the 2024 Olympic Games. It is all about the seamless interconnection of virtual and physical movement and the coordination of every form of flow so that the machine functions without the slightest grain of sand getting in the works, while offering travellers comfort, security and satisfaction (Mouwen 2015). In fact, innovations have been turning up one after another for a long time: magnetic validation terminals for the Orange card appeared in 1975 for suburban traffic. Contactless technology (via the Navigo card) arrived in 2010, at a time when travellers had long been encouraged to buy their tickets from self-service kiosks. Station digitisation soared in the 2010s.

On the one hand, the wave of terrorist attacks in 2015 led to an increase in CCTV surveillance. On the other hand, while smartphone ownership in France reached the 50% milestone, data subscriptions were still expensive. At the same time, following the Brétigny derailment in 2013, major regeneration programmes for suburban lines were planned. Delays and disruption on the tracks could be expected. Station managers, inspired by the idea of mobile working (Marzloff, 2013) and the model of urban third places, responded by espousing digital development. They offered free WiFi and work spaces in stations (Figure 2). Being able to communicate remotely and almost continuously with passengers was useful for warning of train delays or cancellations, but it also played a more central role. At a time when the transport sector was being opened up to competition and the tech giants were gaining a foothold, SNCF was afraid of disintermediation and wanted to maintain constant interaction with the passenger-customer. Interested in connected marketing, station operators introduced another electronic device during the renovation of major stations (from the delivery of Saint-Lazare in 2012 to the upgrade of Gare Montparnasse in 2022). These are so-called Beacons, devices that use Bluetooth technology to track passengers' smartphones, collecting data to provide a better understanding of their travel patterns and behaviour.

Stations have continuously introduced new layers of technology, installed alongside or on top of masses of existing equipment – digital posts and terminals, display boards and screens, etc. – and rendering it useless or

2. Coworking corner at Conflans Sainte Honorine station

From 2016 onwards, as part of the "Gares du quotidien" (Everyday Stations) renovation campaign, station operators began to provide free Wi-Fi and work tables fitted with power sockets (here at Conflans). This form of digitisation came at a time when the Eole engineering works were beginning, causing disruption to trains. Digital options were thus a kind of compensation, enabling travellers to make use of the time spent waiting.

Photo : N. Baron.

obsolete. Little time has been set aside to train people use these new tools or to inform them that new devices are watching them. So technological cycles pass. At present, travellers hardly use free Wi-Fi any more, partly because it does not always work properly, and partly because mobile data plans (which have become significantly cheaper over the last twenty years) are increasingly unlimited. The issues of energy frugality (which stations tout while at the same time increasing the number of power sockets available to passengers), digital frugality (while they continue to build up redundant connection infrastructures) and information frugality, or even 'neuro-rights' (the right to enjoy peace and quiet without being bombarded with information messages) are barely recognised as issues within the company, let alone identified as public problems. They are, however, areas in which environmental, health and social issues and matters of equity come together. (It is quite obvious that first-class spaces are far less prolific in information hype and gadgets and have retained service personnel, whereas day-to-day travellers tend to be served remotely by information technology as stations increasingly become AI hubs.)

Analysing the different aspects of a digital ecosystem

Engaging with railway stations as digital ecosystems means bringing together approaches from several disciplines that share this notion without always attributing the same content to it.

- For sociologists, the term refers to an environment that consists of physical devices (hardware) and non-physical elements (software) with which humans interact. There can be no station digitisation without a series of physical realities and without learning, both of which refract into the digital sphere. The aim of sociologists is to understand the dynamic relationship between people and the digital world, to grasp the evolving layout of station buildings and contents, and to consider how digital entities are apprehended by the body and the mind, by reason and imagination, over a long period of time.
- For economists and rail operators, the digital railway station, or "smart" station (Baron, 2018), is an ecosystem of interconnected actors and objects that exchange information via digital media to generate behaviours. This is the domain of service ecosystems (Akaka and Vargo, 2015) which prompt such things as obedience to instructions or commitment to brands. Technological equipment, whether for surveillance and security, for leisure and gaming, or for travelling comfort, has a performative dimension (Hoitjink, 2015) and produces value (Dulsrud and Bygstad, 2022). Working as a system, they create a sort of second infrastructure that gives the station a new lease of life: software and algorithms modify the lighting and air-conditioning settings, automatically determine the flow of information on the

screens from autonomous inference chains, and answer users' questions. Digital technology generates ambiences and modes of presence in stations with holograms, voices (usually female) and recordings of natural sounds.

– Finally, philosophers of technology have a different interpretation of the term digital ecosystem as applied to transport facilities. They shift the debate from the realm of determinism (are we slaves to these machines?) to the generative dimension of these devices. The digital station prompts new kinds of psychic functioning, activities and practices; it shuts off but also opens up opportunities to act that vary in how easy, how pleasant and how desirable they are (Hollebeek et al., 2019). The relationship between the technological possibilities afforded by stations and the preferences, knowledge and attitudes of users is a matter of negotiation. Passengers are not passive recipients, but actively shape the technological landscape of stations.

This non-deterministic approach is the one we feel to be the most appropriate in exploring the relationship between the passenger, the station operator, the level of digital instruments, and non-digital physical objects such as bags, suitcases and the 'stuff' we take with us or buy on the spot (e.g. a bag of food bought in the station). Anthropologists of consumption point to the deeply cultural and emotional dimension of our relationship with objects, and speak of processes of valuation, devaluation, disinvestment and elimination that are in the realm of conscious and sometimes unconscious action or parapraxis (Holmes, Ehgartner, 2021). Lost objects represent a valuable prism through which to study how technologies function as arrangements that together constitute both the digital mobility offering and the consumption practices of these infrastructures and services.

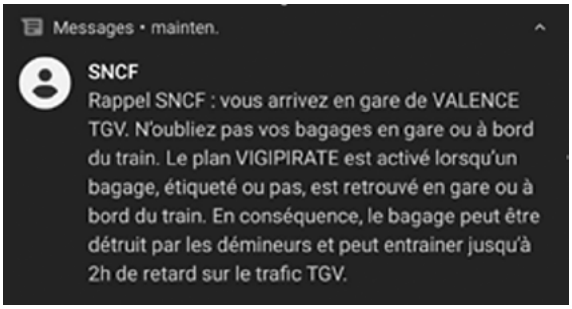
Action and engagement are important terms for understanding the processes involved. During their journey, and particularly as they pass through the station and experience a whole series of contingent situations, including the possibility of losing their belongings, travellers are encouraged to engage with material devices (foremost among them their personal smartphones) and virtual services (applications). The interactive and experiential nature of these relationships with technological entities corresponds to a series of actions (geolocation, notifying personnel, etc.). These actions rely on skills and abilities. All these provisions create the conditions for engagement (Maslowska et al., 2016) with transport operators and other entities (the operators of these specialised services) and determine the cognition, behaviours and emotions of the people concerned and ultimately their experience of mobility. In this sense, technologies are active participants in rather than passive mediators of station life ... and the life of stations.

MaaS (Mobility as a service) for lost property

Methodologically, this section is based on an analysis of the tools provided by the Apple App Store (iOS) and Google Play Store (Android) in response to searches on: 'lost items', 'lost objects', 'lost property', 'lost luggage', 'lost baggage', 'lost bags', 'abandoned luggage', 'lost and found'; 'luggage tracking', 'item tracking', 'object tracking', 'item gps tracking', 'baggage tracking', 'rfid tracking', 'bag tracking', etc. The relevant applications were downloaded, tested and then incorporated into a multi-criteria database that contained a wealth of information, including the release date of the applications, the country where they were developed and used, the number of downloads and the access restrictions. The apps can be divided into two groups:

– prevention tools that attempt to avoid loss by geotagging travellers' personal belongings;
– tools that manage the consequences of loss after the event, and provide travellers with virtual catalogues of lost and found objects.

We will look at each of them in turn.



3. SMS sent to any SNCF passenger: warning against luggage lost

On arrival at the station, automatic push notifications are sent to passengers' smartphones to prevent luggage loss and consequent disruption to station operations (security protocol and train delays). Caption of this original message sent to any rail passenger of French rail system:

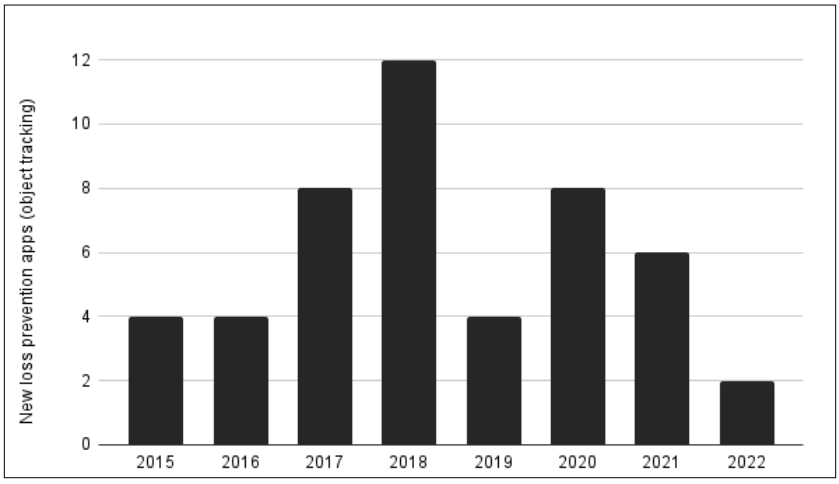
"Caution SNCF - You are You are now entering the Valence high Speed station. Don't forget your luggage at the station or on the train. The vigipirate plan is activated when luggage, whether or not it has an identification tag, is found in the station or on the train. As a result, the baggage may be destroyed by the bomb squad and may cause delays of up to 2 hours on high-speed trains.

Photo : A. Rezanova.

Questions about the *smart luggage system*

Preventive apps communicate common-sense rules to passengers and send text messages when the train comes into the station to warn them to check their belongings when leaving their seat (Figure 3).

They also have other functions. Focused on prevention and the earliest possible identification of loss events (place, time, circumstances), 54 of them offer digital tracking technologies (RFID, Bluetooth and GPS) and the capacity to trace the real-time movements of objects in stations. By comparison with the airline sector, blockchain technology is not much used on the railways (Rodriguez-Ludero, 2019). Many of these tools have both a physical and virtual dimension. They require luggage to be fitted with a tag that calls the traveller's smartphone when the distance between the two (person and object) becomes too great (Ghazal et al., 2016). The travel accessories market is concurrently following the same trend, fitting luggage items with electronic tags, smart locks, built-in scales and sometimes wheels linked to a motor and a small robot that follows the owner everywhere. The rate at which these technologies are being created and brought to market can be seen in Figure 4a: after a sharp surge in the



4. Pace of creation of object loss prevention apps

@ A. Rezanova. database collected for the study

2010s and a peak around 2018, the market is unquestionably slowing down.

This uneven growth can be explained by the dynamics of the market for the media that are essential to these services: smartphones and other personal devices (smart watches). Tracking made headway in the first half of the 2010s with the release of the iPhone 8, which was the first

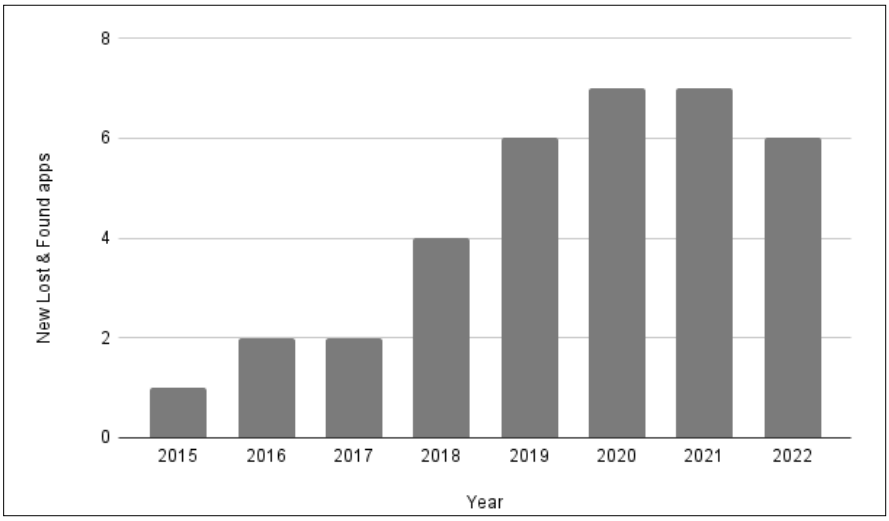
smartphone to incorporate geolocation functions and allow third-party apps to access them. In 2021, Apple launched AirTag and its own Bluetooth tracking tags. Samsung smartphones began to offer these kinds of functions a little later, and this stimulated other digital service developers. As a result, the time-to-market curve accelerated. However, after a peak in 2018, the market appears to have become saturated. But did it in fact really take off? As the range of offerings became wider and competition between developers intensified, people simultaneously present in the same station were sending their data to separate trackers. As a result, the proportion of users of the same type of device diminished, and its effectiveness declined. Bluetooth-based trackers rely on the presence of other users of the same tracking systems (i.e. other users with the same app on their phone with Bluetooth enabled) to identify the location. These tools become more precise and effective when they bring together a large consumer market.

All in all, the smart luggage ecosystem is currently at a technical and economic dead end, as far as stations are concerned (the situation is less cut and dried for airports). Our list, which is inevitably incomplete, shows a market that is both clogged and stillborn. This also indicates the complexity of the nature and size of the connectivity infrastructure investments made in stations: this equipment depends on boom processes but also on commercial flops. The problem is not directly the technology, but the shortcomings of competing marketing methods and the lack of user acceptance. While the authorities expect stations to be increasingly secure, particularly in the run-up to major events such as the Olympic Games, this phase reveals that investment in physical infrastructure and software is not everything.

Virtual lost property offices: a fine idea, but a clear failure

Once a loss has occurred and has been identified either by station management or by a third party, a whole series of physical and digital actions become entangled. Passengers try to notify other passengers in the hope that they will find and return the object, while station staff focus on identification and security. We explored these two worlds in turn by testing 46 apps (80% aimed at travellers, 20% at transport operators). The supply growth curve (Figure 3) shows a more recent growth plateau (2020-2021), but suggests the same likelihood of decline.

The first set of apps (Opinsta, Lost & Found, Faundit) digitises the registration of these objects in the station database, providing the most accurate information possible about the object's features and the circumstances of its loss. It facilitates tasks that until recently were manual and allows interaction between several station sectors. The second set of



5. Trends in the creation of Lost-and-Found apps

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29 apps (TR3ZOR, Lost and Found by Andres Arezo, Found by Found Limited, LostAndFound.com Mobile) are virtual concierge services that link lists of objects and searches. The distraught traveller, who often no longer has a 'stationmaster' to turn to, launches an appeal for help across a community. A third of the apps require personal data to be registered in advance in order to access the content of these concierge services, on the pretext of protecting the real owners from criminals. Some applications, such as Troov, take advantage of the potential of gamification and try to implement the type of matching algorithms used in dating applications such as Tinder. Instead of photos and personal information, artificial intelligence cross-references and matches photos of found objects with photos of lost objects based on their characteristics (colour, size, etc.).

There is an ambiguity in the messages conveyed by the entities that produce the two types of application. They are sometimes presented as complementary and sometimes as substitutes for manual or communicative processes for dealing with objects found in the real world. When developers want to sell these apps to railway companies, they talk about productivity (speeding up routine work) and datastream security. When talking to passengers, they explain that the app speeds up or replaces the procedure for reporting lost property (which is done remotely, so passengers no longer need to return to the station).

In reality, these applications are attempting to replace their biggest competitor, also in the digital realm: social media. Research shows that this field of digital activity has existed on the Web since the launch of the first cpasperdu.com website. Twitter, Instagram, TikTok and others are strong players, but Facebook holds a dominant position: the majority of

people who lose something in a station will automatically call for help from the community of travellers who may have taken the same train or passed through the same station.

To conclude this descriptive section, no market is emerging from this profusion of digital instruments, because a vicious circle is in play. The abundance of applications, each with its own rules and algorithms, produces confusion (travellers no longer know which catalogue to look for their property in) and inefficiency (since fragmentation prevents the development of large databases of objects). One piece of evidence of this dormant market come from the indicators that our survey was able to measure precisely, app by app. Most are not used frequently; many have not been updated for months or years. The number of downloads is small. In fact, 54% of applications have been downloaded fewer than a thousand times, and a quarter fewer than a hundred times. The most popular of these solutions is Traista, because it is able to link the two sides of the digital ecosystem. It is aimed at both travellers and facility operators, and has negotiated a partnership with transport sector entities (the operators of Newark and La Guardia airports in the United States). This territorialisation is certainly one of its strengths, as the others have no territorial roots and have not formed a 'niche' within a company that would have sustained the growth of their ecosystem. Only 11% of these platforms are linked to a particular city (Paris, London) or infrastructure type (a station, an airport) or network (e.g. a hotel chain). Facebook, on the other hand, draws its strength from the very easy conditions of engagement: it has a broad user base across all age groups, and there is no need to register, learn about a new digital environment or provide personal details. Calls for help are therefore more likely to go viral. But you still have to remember where you lost the object, and here we see the reappearance of other facets relating to the tangible and intangible dimensions of the search for lost objects via digital services at stations.

When the virtual world encounters real transport spaces

This section presents a microscale but life-size instance of the possibilities and conditions for passenger involvement in the digital ecosystem of railway stations. We explore the fictional case of a woman, Simone, living in the suburbs of Lille and travelling abroad for a holiday (Figure 5). Carrying her suitcase, rucksack and a small gift bag, she leaves her home in Marc-en-Baroeul to catch a plane at Charles de Gaulle airport. She undertakes the following multimodal journey: Ilevia bus to Lille Flandres Station, then train to Paris Gare du Nord, then RER B to the airport. After taking the escalator, she heads to Terminal 2E, where she waits for

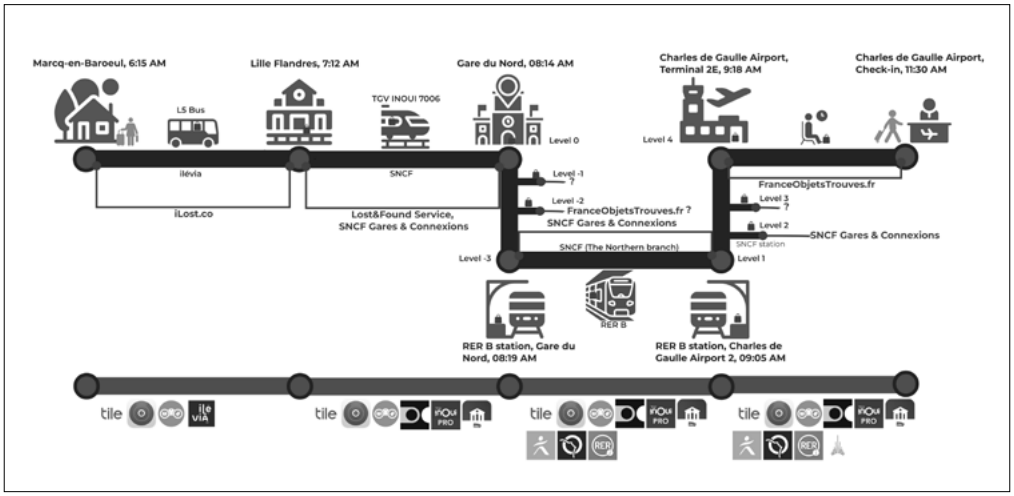
check-in to begin.... but realises that the gift bag has disappeared. She can't remember the last time she saw it. She approaches a staff member who responds casually, telling her that over 700 forgotten computer bags are collected from the boarding satellites at Charles de Gaulle every year. He tells her to check online.

She turns on her phone, connects to the Wi-Fi and app store, and immediately comes across half a dozen apps from SNCF, Air France and ADP. As she is not a transport professional, her idea is to approach three companies that she believes are in charge of the places where she may have lost her bag: the bus company, SNCF and Charles de Gaulle airport. In reality, she ought to distinguish between three categories: transport facility operators (Gares&Connexions, Aéroports de Paris), contract agents that operate the lines on which she travelled (TER Hauts de France and SNCF Transilien for the RER B journey) and organising authorities (for example Île-de-France Mobilité).

The complexity of the institutional and technical organisation of the transport service (and the multiplicity of acronyms, companies and brands) is compounded by the profusion of tools among which each company offers a somewhat different range of services. She selects the applications Ilevia, SNCF Connect, Ma Gare SNCF, TGV Ouigo Pro, IDF Mobilités, Bonjour RATP, RER B, Paris Aéroport and a private tracking app on iOS called Tile. However, these structures offer apps for very frequent travellers (with free access to the press or in-flight entertainment), apps for everyday travellers (which provide real-time information on traffic and disruptions), and apps for specific audiences (people with reduced mobility, blind and partially sighted people, children travelling alone). There are also 3D tours of trains, buses and the various interchange hubs. She also comes across three specialist platforms that give her some hope: francobjetstrouves.fr, iLost.co, and the SNCF Lost & Found service.

Of course, the home screens, functions and environments of each of these tools are different, so the sequences of action required by the software in the different applications are not the same. In order to achieve sociotechnical engagement, Simone has to pass through difficult phases of discovery, adaptation and appropriation (Morgan-Thomas et al., 2020) in order to identify the precise match between the areas of physical space covered by these applications and the journey Simone is trying to reconstruct. The links are not obvious: if the gift bag has been left on one of the escalators between the ground level of the SNCF station and the terminal, which is the right entity to approach?

After an hour of digital wandering and frustration, it's already time to board ... Suddenly, the apparent saturation of the digital ecosystem reveals its gaps, its empty spaces, its shadowy areas. Here, the station's digital duplications shows the discontinuities that the apparent profusion conceals. It's already time to board.



6. Diversity of players and digital tools available for use in a multimodal trip

@ A. Rezanova

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This chapter has looked at how station operators are building a digital ecosystem and inviting users to make use of it. In recognition of the material turn that is driving the social sciences, it has opted to study them as infrastructures in which the logistical dimension and the movement of objects, however trivial and seemingly inconsequential (Bissell, 2009), are increasingly important in the eyes of a number of public and private institutions, in the domains of policing, commerce and railway operations, for a variety of reasons. Travel objects play a key role in the interrelated processes of making stations secure, 'servicing' them and digitising them. These objects weave their physical and virtual instantiations into digital devices (apps) underpinned by a support infrastructure of increasing complexity and cost, which is proliferating at a rate that far exceeds the user's capacity for understanding and appropriation.

There are no stand-alone digital tools for tracking objects in stations. Such tools are incorporated into devices (smartphones and their successive generations) rather than being purchased individually. At any rate, that is Apple's gamble, and it is obviously winning over isolated developers, since a mass scale entity like Apple can work successfully on both sides of the business. The functions for memorising and cataloguing events (the loss of an object) are linked to people, places and circumstances that the smartphone already records, in principle, whether or not the person is travelling.

On the supply side, the dynamic is one of boom and bust. We explain the existence of cycles of creation and destruction in innovation, the impossibility of scaling up and the contradictions between heavy investment in infrastructure – the hardware that makes it operational – and this profusion of not very stable software tools. We show how this ecosystem of digital tools is very much divided between those addressed to station operators and those that aspire to become travellers' companions, or the gap between tools that serve preventive and curative purposes.

Ultimately, the question is whether these digital tools are designed to make mobility secure (MaaS – Mobility as a service) or gadgets created to ingest and resell data (Zuboff, 2018)? The IT developers undoubtedly counted on producing a proof of concept and then relying on the capture of individual data, the resale of customer files and on advertising to move beyond the niche innovation stage and take their place in the digital and economic landscape of MaaS. However, the complexity of the regulatory and institutional regimes in public transport (separation between infrastructure operators, mobility operators and facility managers among the structures responsible for stations), together with the overwhelming power of the tech giants and platform capitalism, have produced a framework for the use of applications that is both over- and under-regulated, receives little support from public actors and is insufficiently territorialised and therefore inefficient. We describe its proliferating reality (brands, forms of showcasing through the physical layout of stations, discourses on technological "solutionism"), all nevertheless resulting in a very disappointing customer experience.

The run-up to the Olympic Games in the summer of 2024 opened up a window of opportunity to change these conditions. Various stakeholders (the state, the police, the urban and rail authorities, the digital industries, the luggage industry, the data protection agency, etc.) have tried to create conditions of engagement for users of the major Paris stations with a view to preventing the loss of property and the ensuing implementation of anti-terrorist security measures that would cause major disruption to operations (train delays, hence congestion and disorganisation). Beyond this inter-institutional coordination, which has yet to be developed, there is a great deal to be done to support users so that they learn to navigate across hybrid domains, i.e. in the parallel jungles of the physical and virtual worlds of transport facilities.

The economic purpose of major stations

Assetisation of mega rail projects and the fertility of capital speculation

Étienne Riot

In 2021, SNCF cancelled the planned concession for the development of Gare du Nord in Paris. The plan had been for the rebuilding and subsequent commercial operation of the suburban lines passenger concourse to be carried out by a "SEMOP" – a single-operation semipublic company. The Auchan Group's real estate company, then called Ceetrus, was to be a partner in a previously unfamiliar environment – the largest railway station in Europe and the third largest in the world in terms of daily passenger flows. It would have been responsible for leasing and managing the many retail outlets included in the architectural programme. The plan was for a new building to be erected on the site of a recent passenger hall designed by Jean-Marie Duthilleul in 2001, with the aim of increasing the density of the existing ramp and bus station behind it. When the cancellation of the concession was announced, Nhood, the new entity that had replaced Ceetrus, sued SNCF for damages. The failure of the Gare du Nord 2024 project – as it was called – is not just another in a long line of urban projects brought to a halt by complex conflicts. It is an exemplary illustration of a factor that often receives little attention in the building of stations, the question of their economic purpose.

In urban studies, economic purpose (dessein économique in French) is a new concept. It is based on the primary definition of the French word dessein, "intention to do something; a project that one proposes to carry through to completion" (Dictionnaire de l'Académie française) and brings together different approaches drawn from the sociology of science and technology, in particular economic sociology. The concept is based on theory of market agencements developed by Michel Callon (Callon, 2013), applied to the case of railway stations (Riot, 2015).

Dessein économique is not the same as economic design, which can lead to confusion. The latter term refers to a field of economics that links different theories (game theory, social choice theory, network economics, Laslier et al., 2019). A study of the occurrences in the various publications of Studies in Economic Design shows that little attention is paid to major physical infrastructures in general, and to railway stations in particular.

Drawing on theories of French economic sociology, we will try to understand how, from the point of view of economic decisions, financial choices and all the tools and rationalities that underpin them, railway stations are formed, deformed and transformed. In order to explore the economic purpose of railway stations, we need to look at the economic intentions and management plans that are the driving force behind their design and operation. This economic purpose can be revealed by observing station development projects, but also in their failures and in the controversies that can arise between the parties involved in them.

Economic purpose projects a rationality of value onto station areas

For a long time, station management was a technical matter, dedicated to ensuring that a potentially dangerous industrial activity – rail transport – could coexist with the management of large numbers of passengers in restricted spaces (Sauget, 2009). The original location of stations, on the edge of urban centres, subsequently became a strategic issue. As urbanisation spread to the edges of cities, station areas in turn were absorbed into the central areas. The expectation of substantial land rents partly explains the periods of speculation around the railways in the second half of the nineteenth century, in Europe and the United States (Dobbin, 2004). Within railway systems, these processes of land rent capture would flourish, particularly in Japan (Doumas, 2008), where Japanese railway companies built entire neighbourhoods close to tracks and stations (Aveline, 2016).

This distinctive partnership came to a halt in countries that opted for state ownership of the railways (Italy in 1905, France in 1938 and the United Kingdom in 1948). The stations were integrated into a network system. Their priority would be functional, focusing on train operations, with complementary activities – whether in commerce or real estate – necessarily relegated to a backseat role. These developments, linked to a situation of state control, were accompanied by major transformations in mobility cultures and practices. The development of long-distance commercial aviation and the intensification of car use helped to transform the expectations and practices of rail passengers (Ribeill, 1996).

From the late 1970s, the development of high-speed lines transformed the planning and management of stations. As access points to a network on which journey times were drastically reduced, stations became hubs for new forms of mobility in competition with aviation: high-speed long-distance commuting for executives, departures from and arrivals in urban centres, but also the insertion of so-called "beetroot" stations (remote stations outside urban centres) on new lines on the outskirts of big cities. A new economic vision thus began to emerge in the 1990s. It linked a perception of the commercial potential associated with a captive high-speed business clientele – who became targets for the capture of purchasing power – with the Europeanisation of rail systems. The construction of the European rail market began with Directive 91/440 of 29 July 1991, which separated infrastructure from transport services. This document and those that followed accelerated the singularisation of stations in the rail system (Riot, 2015). A new type of player emerged, the station operator, which based part of its business on fare engineering and modelling the economic value of stations. Acting on behalf of railway companies, private investors and public regulatory structures (Baron, 2021), these bodies (in France Gares & Connexions, in Germany DB Stations and Services, in Italy Grandi Stazioni Rail, etc.) are the platforms on which the economic purposes for stations are forged. The implementation of the European rail market led to the establishment of independent public regulatory bodies – the Autorité de Régulation des Transports in France, the Autorità di Regolazione dei Trasporti in Italy, etc. – which helped to organise the different value frameworks between the players (Riot, 2015).

– In practice, the rationale behind the projection of the economic value of stations followed different paths from one country to another. The balance depends on local interests and cultural acceptance. The station is subject to a threefold market agencement (Riot, 2015):
– it is an essential infrastructure within the meaning of competition law, which must be organised in such a way as to allow access to all railway companies;
– it is a real estate asset whose location and development are subject to valorisation between public and private players, as we will see later;
– it is a market place, home to a large number of businesses that aim to serve the flow of travellers and passers-by in order to derive economic value from them through systems of rents and commercial concessions (Figure 1).

The assetisation of stations puts value streams into circulation

The proliferation of retail outlets in railway stations, especially the larger ones, has generated debates about the supposed commodification of the station (Duteurtre, 2012).

As Birch and Muniesa (2020) demonstrate, it would be too simplistic to consider contemporary economic exchanges solely in terms of the values generated by the intrinsic qualities of a commodity at a given moment in a transaction. These authors encourage us to consider goods not as commodities, but as assets. Compared to a commodity, an asset is "something [that] can be owned or controlled, traded and capitalised as a revenue stream, entailing the evaluation of discounted future revenue in the present" (Birch, Muniesa, 2020, p 2).

Stations fulfil all the criteria defined by Birch to characterise an asset.

– They are legal constructs whose contours are defined by a regulatory process, whether through a long history of regulation or through the contemporary organisation of oversight arrangements via the regulatory authorities.
– They are owned and controlled in different ways – in France, for example, even though private real estate companies control the development of commercial areas such as Saint-Lazare station, the station remains an integral part of the state's public railway domain.

1. The Relay store in the Eurostar area at Gare du Nord: serving high-contribution passenger flows

Photo : N. Baron.

- Extraction of their economic value is a sophisticated process that requires public entities to be involved in its establishment.
- The development of public-private partnerships is not a smooth process and can lead to stresses, as the case of Paris Nord 2024 has shown.
- Station operators form natural monopolies, so increases in the value of stations do not result in new players entering to create or manage them. In other words, injecting additional capital into stations does not lead to the emergence of new station operators.
- The value of stations can be discounted on the basis of expected future returns, whether or not those returns are realised.
- The assessment of this value can be modified by the owner, in this case the state, depending on the value stream and the partners it wants. (This will be shown in the Italian case later in this chapter).

So a station is not a commodity but rather an asset. It is altered by complex processes of qualification and quantification around its rough edges, its functions and its projection in time. At St Pancras, Milano Centrale or Roma Termini, this logic is very important to understanding why and how the stations were developed in the 2000s.

Specific instances of assetization

St Pancras International (Figure 2) was renovated as a terminus for high-speed trains and for the Channel Tunnel rail service. It was part of a £2.1 billion public-private partnership signed in 2010 between the UK government and a consortium of investors led by the Canadian pension fund for Ontario civil servants. The aim of this public-private partnership was to achieve medium- and long-term profitability from a transport infrastructure identified as enjoying low exposure to risk. At the heart of the concession, stations located on the high-speed line, including St Pancras, are assets that can be used to generate additional resources – via car parks and, above all, retail outlets. The contract between the investor and the government stipulates the 40-year concession period and programmes the level of investment in the station required to keep it in good working order (Riot, 2015). In 2017, the Canadian pension fund sold its concession to a new consortium of investors (InfraRed, Equitix and the South Korean national pension fund) for £3 billion. The specific characteristics of transport infrastructure, its highly technical character, and the cumbersome nature of its regulation and management do not make it an easily tradable asset. What is taken into account in these transactions is the long-term flow of value expected by the financial players. For the investment consortium's operational teams, the challenge is to maintain the infrastructure's inherent qualities in order to ensure that it continues to generate the expected value. This requirement translates into constant pressure to maintain rail facilities

at a high standard and in good condition, both for transport activities and station-based commercial activities.

In Italy, the major railway stations are at the heart of an economic plan that has grown steadily more sophisticated. In the early 2000s, the Italian government embarked on a programme to restructure the country's major railway stations in order to exploit their commercial potential. To attract private investors, a division of labour was introduced between a public commitment to renovate and improve the intermodality and safety of stations – the Grandi Stazioni programme – and a public-private partnership to renovate and convert major stations into shopping malls. A view of Milano Centrale station illustrates this shift towards commercial activities (Figure 3). In the turmoil of its 2015 austerity plan, the Italian government accelerated its value enhancement strategy. The Grandi Stazioni entity was divided according to its different roles: Grandi Stazioni Rail

2. View of the shopping arcade at St Pancras Station (note also the bar on the upper level of the boarding area)

Photo : É. Riot.

for transport operations, Grandi Stazioni Retail for commercial leases. The latter was sold for one billion euros to a Franco-Italian investment fund. Through advertising, staging events, the installation of temporary shops and the management of commercial leases, Grandi Stazioni Retail works to increase the flow of commercial value in stations. In 2023, the investment fund that owned Grandi Stazioni Retail announced its intention to sell the company, for an amount based on the projected financial value of Italy's major railway stations (Carosielli, 2023). These examples from the UK and Italy show how the value of railway stations is put into circulation through the process of assetisation. However, this process can be fluid or subject to tensions, as it is in France.

3. The omnipresence of commercialism (shops, advertising) in passenger journeys at Milano Centrale station

Why and how the Paris Gare du Nord and Grand Central projects went off the rails: when financial value conflicts with heritage value

In the early 2010s, the French station operator Gares & Connexions and the regional authorities were having a hard time agreeing on the accounting principles to be applied in assessing the return on the capital injected by SNCF into station renovation projects. In a nutshell, Gares & Connexions compared itself to a private airport operator, applying equivalent risk criteria that were reflected in the return on its capital, which was part of the access fee charged to regional transport authorities. These authorities, run by the regional councils, were also expected to invest directly in station renovations. The regional councils felt that they were paying twice for station projects, once via the initial investment in the renovation work and a second time via the access charge to regional express stations. This question, technical though it was, revealed a clear disagreement between the parties over who could legitimately decide on the economic order of the station. It emphasised the crucial importance of defining and controlling financial flows in station projects and management. The accounting controversy was merely the visible aspect of deeper tensions (Miller, 1998) around station economics caused by newly emerging players. Beyond the tensions, this example is consistent with Finger and Messulam's view that station access charges are public policy instruments rather than financial instruments (Finger and Messulam, 2015).

The economic purpose of stations is just one of the variables that contribute to planning and management decisions. Although it is the overriding factor – since it remains central in determining the capital invested – it can be influenced by other factors. It is in situations of overspill (Callon et al., 2017) that this economic purpose is most clearly seen and also regenerated. The failures of the New York Grand Central and Paris Nord 2024 real estate development projects are emblematic of thwarted economic purposes where tensions arise between players who draw on very different rationales to justify and pursue their interests.

New York's Grand Central station has been an important asset for the companies that have successively controlled it. In 1903, the railroad company that owned the station set up a real estate subsidiary to develop the adjacent land. This project, known as Terminal City, led to the rebuilding of the station in 1913 and the emergence, above the tracks, of an entire district, which was completed in the 1930s. The station contributed to the development of the Park Avenue district and became the epicentre of the flows irrigating the hotel and office towers (Belle and Leighton, 2001). In the early 1950s, the success of the real estate operation stood in stark contrast with the economic difficulties of the railroad companies. Faced with the rapid development of the car industry, these companies were keen to diversify their resources and initiated a new real estate development plan called Grand Central City. The architectural quality and unity of the new district helped to increase real estate values (Schlichting, 2001). Air rights – the real estate interests in the potential areas of construction above the station – rose sharply in value. Compared with the 1903 plan, the real estate project was no longer limited to the adjacent land, but also incorporated the urbanisation of the station building itself. For twenty years, until 1978, the Grand Central City project tried to have the historic 1913 station demolished and replaced with skyscrapers, of which only the PanAm Tower, now Metlife, was ultimately built. A conflict arose in 1969 between the railway company, with its economic vision for the development of its air rights, and New York City Council, which had just passed a heritage protection bylaw (Clausen, 2006). In 1978, the legal battle went all the way to the Federal Supreme Court, which upheld New York City's decision to prevent the demolition of the station on the grounds of its heritage status. This heritage turn (Riot, 2016) marked a watershed between the different scales of appreciation of the station's value. Heritage value, as defined by local regulations in conjunction with national public policy instruments, was considered to take precedence over the building's strictly local real estate value.

At the heart of the controversy, the opposition between the two models of value projected onto the station reveals the frictions and tensions in the projection of value streams imagined and constructed from the standpoint of different rationales. Opponents of the tower project saw the station as a means of marking the city's historical identity and perpetuating a link

with the past for future generations. For the backers of the tower project, the station represented an opportunity and an asset for the capture of value streams.

Though different, the failure of Paris Nord 2024 also reflects a conflict between economic purpose and heritage value. The economic purpose for Paris Nord 2024 was initiated by a national ambition for the Gare du Nord to match the standing of London's St Pancras station. During the national tourism conference, then Minister of Foreign Affairs, Laurent Fabius, whose prerogatives include this domain, announced his political ambition that Gare du Nord, "Europe's leading railway station, [should] be able to stand comparison with Saint Pancras in London". This led to intense discussions within SNCF on how to improve the station experience. A masterplan was drawn up in 2015 under the title "Gares du Nord Transformations 2015-2023" and entrusted to the architect Willmotte, on the basis of the rail programme initiated by AREP, SNCF's in-house project manager. This masterplan contained proposals for a large number of changes to the station area. In 2017, the new law on the organisation of the Paris metropolitan region authorised the formation of single-operation semi-public companies (SEMOPs) for major infrastructure projects, an instrument geared towards the Paris Nord 2024 project. The aim of the SEMOP was to bring SNCF into partnership with a private investor which would be responsible for building and then jointly managing the commercial side of a new passenger concourse, for a concession period of around thirty years.

It was during the definition of the final project, for which the SEMOP was formed, that the economic purpose that had slowly emerged triggered intense controversy between numerous parties. The private investor selected for the SEMOP was Ceetrus (now Nhood), a real estate subsidiary of the Auchan Group, at the time an unknown in the rail community. The final architectural project, developed by the Valode et Pistre agency, gave pride of place to retail spaces, lengthening certain passenger flows for that purpose, and optimised the land potential of the plot where the new concourse was to be built. This architectural project was consistent with both the technical and financial specifications. However, it immediately attracted opposition from a group of architects and town planners, whose article in Le Monde (Collectif, 2019) criticised its economic priorities. In the end, the Mayor of Paris joined the opposition to the project, to the point that the tension between the parties prompted the Prefecture to initiate mediation based on new expert assessments. Finally, in 2021, as SNCF and Nhood delivered varying estimates for the cost of the construction works, Gares & Connexions objected to the concession on the grounds that the budget was much higher than expected. The project was shelved and replaced by a more frugal version, with no capital sought from a private investor.

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FAll in all, the economic purpose of major stations raises questions about the value streams that pass through them, the timeframes in which they operate and the rationales that emerge from them among station developers, operators and investors. The architecture, organisation and experience of stations are thus in thrall to an intangible yet essential factor. The economic purpose is not set in stone, it is not an iron law that imposes itself on station spaces, but a constantly negotiated dynamic. It is a system of rationalities that can come into conflict with others – as instanced by the thwarted plans in New York and Paris – to the point of generating different futures for major stations in the heart of cities.

Caring for vulnerable populations and refugees at a railway station

Norélia Voiseux

As a space that is open to the city and to society, a train station is a nexus of multiple economic, political and human issues. This zone of transition and of encounter between people from all walks of life attracts not only travellers and clients, but also more unconventional populations, for whom the station can be a refuge or a hub of resources (Damon, 1996).

Railway stations have always been exposed to petty crime, exclusion and homelessness caused by extreme poverty, which therefore require special care and attention.The first railway companies had already taken measures to combat antisocial behaviour and public disorder in train stations. Today, security-related, economic and legal factors raise new questions. At the turn of the 2000s, French stations underwent a spatial transformation, to accommodate high-speed lines, to meet European requirements for competition in the rail sector, and make space for more retail outlets (Gasnier, 2007). Thus, rail stations are gradually designed to accommodate the best resourced populations. The reallocation of space to new commercial functions had the effect of crowding out less lucrative activities linked to the historic function of dealing with the poverty. Reception and assistance facilities, and solidarity programs were gradually closed or relocated.

This movement of appropriation and dispossession is linked to a more general urban phenomenon: gentrification (Authier & Bidou-Zachariasen, 2008) and emerging mechanisms ofresistance to this gentrification (Shaw, 2004). The question we ask here is how such resistance is maintained in the context of a company as SNCF ? How could reconcile the company's social commitments with the processes of spatial withdrawal of solidarity facilities in train stations? What What are the dynamics of confrontation and resistance generated by this transformation of the company, where do they play out, and with whom?"Is the company unified in its responses or are re movements of opposition and resistance? And if there are, what investigative methods can an external researcher use to identify them?

After revisiting the history, role and development of the social support function in the railway sector (section 1), we will focus on the lastest social

facility located in the Strasbourg train station: the Welcome and Solidarity Point Drawing on this specific case study, we demonstrate the existence of an unusual form of resistance to the ongoing modernisation – or gentrification – of contemporary railway stations (section 2). A concluding section will discusses the ambiguity in the railway company's attitude to social support initiatives in train stations.

Theoretical and methodological frameworks

The historic role of railway stations in providing assistance to vulnerable populations

When the first passenger lines opened", the train was a new mode of transport confined to an elite, but also an object of attraction for more disadvantaged populations. Railway stations were exposed to begging, prostitution and theft, and security measures arose very early on to repel undesirables.

After the Second war, the railway company was given a mission by a "community-minded welfare state" (Chevalier, 1994) to contribute to the territorial and social construction of the country. Prisoners of war and deportees returning to France received assistance and health support in railway stations. Based on the values underpinning the ideal of public service, which were already part of the "railway spirit" before nationalisation (Chenot, 1956), SNCF became a key player in national solidarity measures. During the crisis of the late 1970s, the homeless flocked back in railway stations (Damon, 2003) attracted by their various resources - a roof and warmth, passengers to turn to for help or to beg (Höjdestrand, 2011). Little by little, as extreme poverty increased, the number of homeless people in train stations rose in France and elsewhere (Domingo, 2007; Ghatak & Guchhait, 2022). This phenomenon pushed the company to increase efforts to fight against extreme poverty. In 1980, SNCF supported the creation of the "SOS Voyageurs association", which provides assistance to anyone in difficulty (victims of theft or people being lost) in train stations. But this was not enough to prevent the situation deteriorating, particularly with the increasing immigration movements from Eastern after the fall of the Iron Curtain.

At the turn of the millennium, SNCF redefined its public service missions in the light of sustainable development, and was committed "to assume special social responsibility by pursuing solidarity, prevention and anti-exclusion measures" (SNCF Public Service Charter 2004). The issue took on a more societal dimension within the context of the CSR (corporate social responsibility) approach: from 2012 to 2017, CSR report recall the historic role of SNCF in providing assistance to the most disadvantaged people, but the situation and the discourse has changed since then.

New ways of operating stations less compatible with solidarity

The liberalisation process brought profound changes to the rail system. Stations have played a critical role in this movement, as they are essential infrastructures for competing transport operators. SNCF's Gares et Connexions business unit was created in 2009 to support a new business model, in the mid-2010s: City Booster. The aim was to gradually convert railway stations into urban hubs with better connections to the city, not only in terms of mobility, but also in terms of urban, economic and social synergies (Gasnier, 2007; Ropert, 2017). In addition to its transport and intermodal functions, train stations were to develop the commercial life and services (Zemp et al., 2011; Capo and Chanut, 2015), and to play a functional role in the metropolisation process (Albertelli, 2022). Behind the idea of recovery and of creating hybrid places with combined spatial and digital connections (Deparis and Paquier, 2019), there is actually a capitalistic and neoliberal vision of the city (Van Criekingen, 2008), based on the commodification of spaces and functions.

The spatial distribution of the station has been used to integrate chains stores (Dang Vu and Jeaneau, 2008), which could generate incomes five times higher than traditional shopping centres (Gaillard and Marton, 2018). Spaces inside train stations are redesigned to combine fluid passenger movement with this commercial strategy (Baron, 2019), following a model already applied in airports (Welté and Ochs, 2015) or the metro (Tillous et al., 2008). Figure 1 illustrates the changes that have undermined the role of train stations in providing assistance to vulnerable populations.

Under these circumstances, less lucrative activities have been downgraded, either rationalised or even eliminated. Dealing with homelessness and poverty has gradually been outsourced from train stations. Gares & Connexions signed agreements with specialist and voluntary organisations: by 2021, nearly 80 agreements covered the needs of 70 train stations. This change in social issues management is a way to deal with increasing land pressure, by relocating unprofitable social support activities, and regaining the space they previously occupied free of charge. Places where assistance was provided to homeless people were gradually closed or moved outside train stations, and gradually disappeared as French stations were modernised.

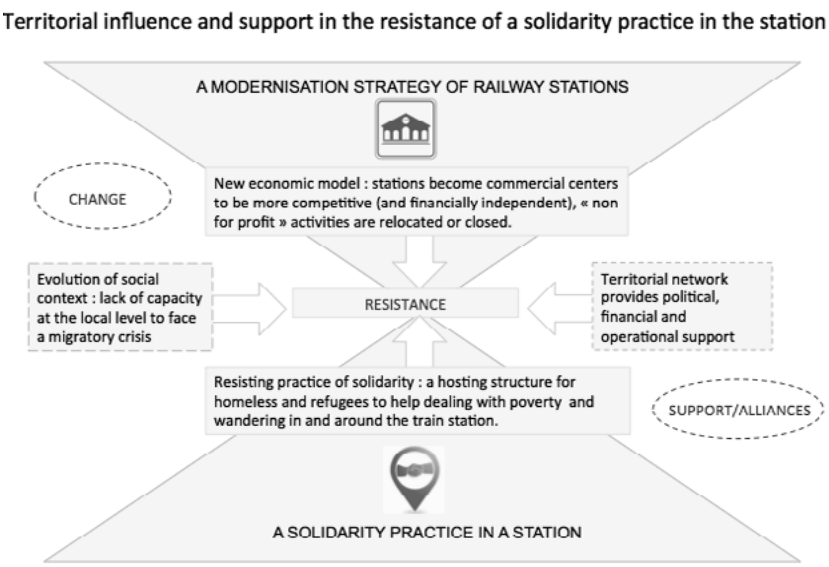
Another model for dealing with homelessness in railway stations

Solidarity support: a matter of responsibility which create tension between corporate and territorial stakeholders

As emblematic places where SNCF's public image is on display, train stations are a central issue of its social commitment. From the earliest CSR reports, the fight against exclusion and extreme poverty in railway stations was one of the company's priorities. In a document entitled "Supporting people in difficulty", the company demonstrates its historic role in supporting the most disadvantaged people. At the same time, however, social facilities for homeless people located in train stations are shrinking. SNCF gradually outsourced this function in building partnerships with external stakeholders in order to have more effective action across the country and to harmonise the multitude of local initiatives, which varied greatly from a station to another. The company moved away from dealing directly with these issues at an operational level: that is particularly visible from 2018 onwards in the CSR reports, where there is no reference to homelessness or poverty anymore. The non-financial data published by SNCF in 2021 confirm this decline of social priorities in railway stations, now limited to prevention and safety issues. Although the company emphasises financial support to social facilities and accommodation centres located next to certain train stations, there are almost no more solidarity programs in the train stations themselves, excepted in Strasbourg station. This "Solidarity Welcome Point" is the last remaining social facility that is visibly resisting a series of pressures: spatial and commercial pressures because of the modernization of train stations, but also internal pressures within the company itself.

Research question and method

This study focuses on the contradictory processess at work in the SNCF company, between the maintenance or elimination of this social facility in the Strasbourg train station. Our hypothesis is that it could be characterised as a kind of resistance to the gentrification process of train stations: not an ideological resistance against a top-down neoliberal power, but rather a resistance rooted in practice (Efros, 2007). This is a less visible type of resistance which enables employees to find commitment, identity and sensemaking in work (Courpasson et al., 2017), keep their autonomy and stand to some of their own convictions (Sanson and Courpasson, 2022). More discreet, this form of resistance filters into ordinary everyday practices, activities that are not supposed to take place and that challenge the dominant logics and priorities of the organisation. It can also shape a form of adaptation and create resilience (Bernard, 2007; Casevitz, 2022)



1. Confronting the need to modernise and to maintain social facilities in train stations

@ author

We studied this resistance through the monograph of the "Reception and Solidarity Point" (RSP) at Strasbourg train station (Figure 2). Although the research findings could not be generalized, this method enabled us to conduct an in-depth analysis of a real situation experienced in the field, and to focus closely on the background feature of the story. We carried out in-depth investigations between June and December 2017: phases of observing activity, interviews (around twenty) with various individuals identified for their engagement and involvement in its fonctionning. The sample was selected opportunistically, using a bottom-up approach to identify local actors (at the RSP and in the train station), and tracking back along the upstream decision-making or functional management chains (Gares & Connexions and other SNCF departments). Most of these interviews were one-to-one (face-to-face or remote), but some group interviews could have been conducted for example during team meetings or when interviewees came up with their collegues. Some interviews were conducted on the move ("commented walks", Raulet-Crozet and Borzeix, 2014), i.e. by following the person on a visit or during an activity, which was an opportunity to study the action in its context, using the researcher's body as a research tool. Each interview was audio-recorded and transcribed for thematic processing.

2. Photographs of the exterior (left) and interior (right) of the Reception and Solidarity Point (RSP) at Strasbourg train station

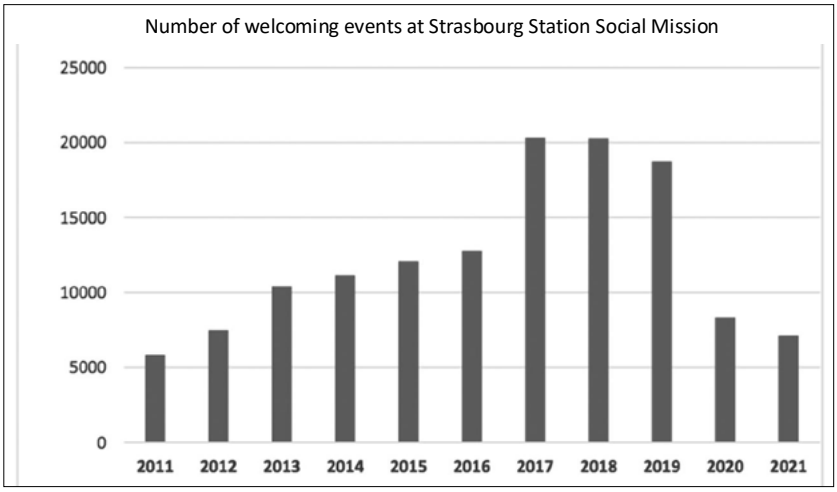
Source : Source: RSP activity report, 2016, p.38, (no further use allowed)

Internal resistance to the outsourcing of station-based social support activities

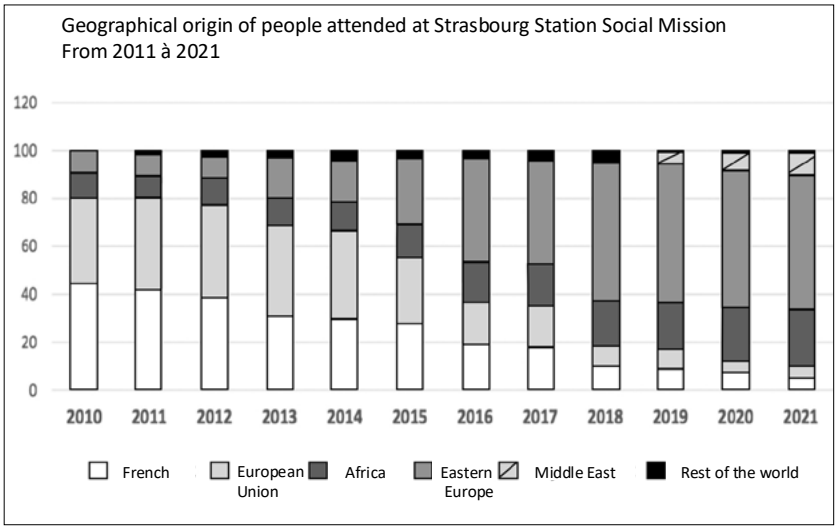
The Strasbourg Reception and Solidaruty Point

The RSP is a facility set up by SNCF at Strasbourg train station in the late 1990s to deal with vulnerable populations – mainly homeless people – and, if necessary, direct these people to appropriate local structures. To carry out this task, the RSP was located within the station, but in a separate space, in order to maintain a degree of confidentiality when these people are welcomed and cared. SNCF covers a large part of the structure's operating costs (around 70%) and employs a full-time staff member to be in charge of the reception point. Four social workers also joined to the team helping to keep the place opened every working day of the year.

Since the end of 2016, the increase in migration movements has significantly changed the RSP attendance (initially composed of local people), and began to welcome more en more people fleeing their homeland and seeking asylum as refugees (Amnesty International, 2023). Today, 95% of RSP visitors come from Eastern Europe, Africa and the Middle East, and they have increased exponentially: in 2017, over a hundred different people came through its doors of every day (Figures 3 and 4).



3a. Evolution of the number of visitors



3b. Breakdown of visitors by geographical origin

3. Trends in the number of people supported by the RSP between 2011 and 2021

Sources : Rapport d'activité du PAS (2021) : 13 et 16 (no further use allowed)

The receptive point, a symbol of resistance

Our study shows that the continued existence of the RSP at Strasbourg train station depends primarily on an individual choice to resist on the part of the reception point manager. The transformation of train stations to the detriment of humanitarian activities such as the RSP is in line with the decline in social

values inherited from railway culture. This can trigger singular behavors on the part of some staff, who wish to regain a form of moral alignment. The RSP manager is committed to defending this social service in the train station, despite the commercial pressures that might lead to its erasure.

> "And what would be the point of making a SNCF service and taking it out of the station ? I want us to stay in the station, and that's what I told them, I said that our job is linked to the station, there's no reason for us to be 500 metres away from there."

This personal commitment to solidarity values can be likened to a form of moral entrepreneurship, a desire to foster a certain vision of the social question in train stations and in the railway world. The RSP manager's struggle is based on human values and she campaigns to have reliable allies within the company. However, it was difficult to obtain internal support at a time when the railway company had embarked on big changes that would lead to the disappearance of this type of structure in train stations. Despite the increase in the number of visitors and activities, the RSP has not managed to obtain real recognition and additional resources to facilitate its day-to-day operations:

> "It's good that we're still going, but if we are vulnerable ourselves, it's tough. At one point, we had a director who didn't say hello, didn't come in, looked the other way when he passed us. You always have to fight," she laments.

She tries to reassure herself with the commitments made at the top of the company, and promote a coherence between the RSP's actions and the corporate responsibility priorities.

> "It is through a strong CSR strategy adopted at all levels that the RSP will be able to continue doing its work at Strasbourg train station, with the pride of pursuing a unique and atypical project within the company over the years" (Conclusion of the PAS progress report, 2021).

However, the work of RSP is barely mentioned in the 2015 and 2016 CSR reports and then disappears altogether, and finally disconnect from the CSR policy.

> "The question about the company's commitment is whether or not we should continue with this, not that it isn't a good thing to do, but is it SNCF's role today? We need to come up with something that can be replicated methodologically across the country, which also means that we have to do the marketing, because there's no shame in presenting these societal issues as business enablers as well," explains one director.

Lack of support inside the company led the RSP to get financial and institutional support from elected representatives and local social cohesion

network. Since the past few years, its survival has on an annual subsidy from the City of Strasbourg and the Bas-Rhin Department.

The continued existence of RSP in the train station were given find that unplanned exposure with the migration crisis of winter 2016 associated with the war in Syria. As one of the social workers at the reception point rightly points out:

> "When you have no papers, when you're waiting for a reply to a request made to the prefecture, when you have no accommodation, what place is open in a city where you can stay?"

On the front line, the RSP continued to prove its value, although the structure was not always suited to deal with these new populations (translation, asylum rights and procedures, presence of minors). By providing initial assistance for these people as soon as they arrived in the region, the RSP became an essential partner for the authorities, which lacked the resources (the city only had one day centre at the time) to deal with the scale of the crisis. The difficulties raised by these new circumstances provided the RSP campaign with a powerful argument to justify its role and its value to the territory, as witnessed by the awareness of this Regional Director:

> "It would be more of a risk to me if I got rid of it, because it would cause a big stir, including political pressure from the city, elected representatives and civil society organisations, but from outside"

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The reception point at Strasbourg station is the last French social support facility to have been protected and maintained (adapting its activity to the local context) its position in a train station, while the other social structures have disappeared under the pressures of the new commercial approach to managing the railway stations.

Keeping the RSP in the train station instantiates a form of resistance at the interface between two apparently contradictory currents: on the one hand, a dynamic of economic rationalisation initiated by the railway company, and on the other, a social and solidarity-based response to the problems of great poverty.

This case study showed that this humanitarian resistance at the train station was the product of a campaign led by the reception point manager acting as a moral entrepreneur. This stance has acquired renewed legitimacy in the context of the geopolitical crises which perpetuate today in Ukraine war. If the resistance embodied in the RSP has been opportunely embraced by the railway company, it is eventually a way of combining the expression of humanitarian values with the demand for station profitability, as part of a CSR policy effectively connected with territories.

The potential of Beirut's abandoned stations: An illustrative application of actor-network theory

Christelle El Hage

The reclamation of abandoned railway lines has produced a common narrative over the last four decades: the closure and loss of railway activity, followed by disuse blight and ruin, followed in turn by the rediscovery of railway spaces and their repurposing for public use. This process is only the contemporary phase of a much longer railway history. The global boom in railway construction during the 19th century played a major role in the urbanisation of cities. Less than a century later, faster modes of transport rendered many railways obsolete, often leading to their abandonment. As railway infrastructure falls into disrepair, each city uniquely reclaims its structures and spaces. This reappropriation often starts with informal practices that precede and sometimes anticipate official efforts to turn these infrastructures into greenways, bike paths, and parks. New York's High Line falls into this category, and is seen by some as a successful model for rail-to-park transformation (Littke et al., 2016), and by others as a thinly veiled attempt to boost property values through eco-gentrification (Black and Richards 2020). As these opposing views indicate, such processes are often judged on their final outcome, while the complexity of the interactions involved in them receives far less attention. The finished High Line Park represents a stable actor-network, and a resolution to the indeterminancy of previous networks. The abandoned (pre-park) high line was a more complex, unstable actor-network of human, inanimate, and biological ecosystems. These actors and their networked interactions mostly disappeared with the finished park and the increasing gentrification of the neighborhood (Lindner & Brian, 2017).

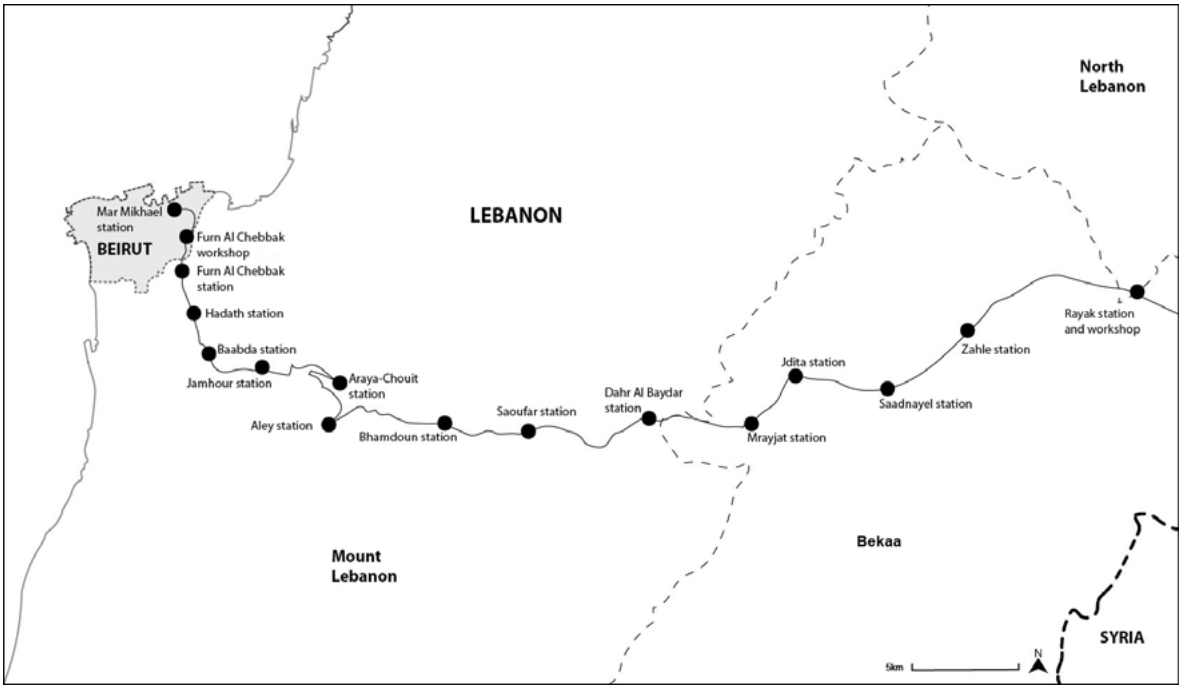
This chapter examines the spaces and structures of the abandoned Beirut-Bekaa (BB) railway as complex actor-networks where actors vie to re-define and recharacterize the spaces according to their use. The first part of the chapter presents an overview of the history and the context of the railway line, which is officially considered abandoned and has been closed to the public for almost two decades. The second part presents a

methodological framework based on actor-network theory (ANT), adapting the concept of network ruins to examine how these uses interact dynamically with forces of decay, growth, and reuse to create a constantly evolving network ruin (Qviström, 2012, p. 257). The third part of this chapter attempts to map the uses and users of this line and these stations and to characterize their complex relationships. This map represents doctoral work in progress and should be understood more as a proof of concept than a final product. However, we believe that it provides a tool for investigating and understanding the way in which certain actors exert forces of inertia or transformation on this line and these vacant stations.

History and context

Constructed between 1891 and 1895, Lebanon's first major railway linked Beirut and Damascus via the Bekaa Valley, as a consequence of Beirut's growing economic strength in the region, the Ottoman Empire's need for centralized control after recent revolts, and the economic threat of competing lines proposed in Haifa and Jaffa. Until 1956, when it was nationalized, the Beirut Bekaa Railway operated on several levels: on an international scale (as an integral part of the Middle East rail network), as part of a wider transcontinental network linking London to Mecca by rail, and also on a regional scale, allowing goods to be imported and exported to and from the Mediterranean. As the Arab-Israeli conflict came to dominate the region's political and military landscape, international rail transport became a threat to the security of foreign powers and, as a result, less profitable for Lebanon (Verdeil et al. 2019). At the same time, gas and car subsidies fueled increasing reliance on highways and private automobiles, as well as a growing car culture (El Zein, Carrouet, 2022). Funding for the railway was cut in 1964. Branch line closures and disconnections became more marked from 1967 onward, when relations with Egypt and Palestine were made impossible by the war. From the onset of the Civil War in 1975, sporadic rail service for freight and military purposes slowed and eventually stopped in 1991 (Figure 1).

Since 1991, the railway infrastructures of the former line from Beirut to the Bekaa have fallen further into disuse and despair. Nevertheless, they are alive with growth, activity, and constant change – the sites of a vibrant network of forces and actors which is informed by the line's complex history, and which will undoubtedly inform its uncertain future. These spaces have at times been partially re-appropriated by residents, used as unsanctioned pedestrian corridors, repurposed for art installations, deployed as settings for films, or simply been allowed to develop as untended, urban green corridors with high ecological value. They have also been the site of incomplete private development as pop-up nightclubs, restaurants or parking lots,



1. Location of the stations along the Beirut Bekaa Line

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and the subject of numerous plans for redevelopment and feasibility studies yet to come to fruition (Malkoun, 2021).

Despite the prevalence of Highlines, Promenades Plantées, and other old railways converted to parks, cafes, or bike paths, countless tracks and stations around the world remain in ruins even in urban areas where space is at a premium. Such is the state of the Beirut-Bekaa line.

This chapter therefore starts with a simple question: why have the Beirut-Bekaa line and its associated structures remained in ruins rather than being repurposed? There are already a host of extant and potential answers with significant explanatory power, including:

- market forces have yet to make the value of reclamation outweigh its cost;
- olitical corruption thwarts public works development (Noeth, 2019, p. 159);
- sectarian insularity reduces demand for shared public space;
- foreign political and military interests exert pressure against a rail-connected middle east;
- foreign economic interests promote automobile over rail transport;
- limited resources devoted to top-down urban planning;
- insufficient support and advocacy of underserved communities with ground-up developments;
- more immediate crises have constantly plagued the country.

These "broad stroke" explanations – while valid – feel general and conclusory, with insufficient detail – as if they were based on an idea we already have of what must be happening. Moreover, investigating these specific reasons already biases the result toward the theoretical or ideological framework implied by the explanation. In fact, the dynamics of stalled development around the Beirut-Bekaa line implicate a wide range of forces and actors operating in a complex and ever-shifting network that requires a more precise analytical tool unmoored from theoretical or ideological preconceptions.

Actor-Network Theory and urban railway spaces

Actor-network theory (ANT) provides an investigatory tool to explore the complexity of these networks. Based on the research of Bruno Latour, Michel Callon, Madeleine Akrich and John Law (Williams, 2020), this approach examines and maps the interactions among human, natural, material, social, cultural, and semiotic entities (actors/actants). Latour and other theorists posited that ANT could "undermine and problematize" traditional notions of space, scale, distance and geography by revealing the actor-networks that construct these understandings, and the actions they prohibit or encourage (Latour, 1997, pp. 4–5; Murdoch, 1998, p. 359). This theory shifts the focus away from spatial and geographical relationships, treating them simply as another type of network connection linking actors in an urban environment (Farías & Bender, 2009). Although a full discussion of ANT is beyond the scope of this article, a few key principles and starting points may be helpful.

Generalized symmetry

This entails treating all the actors in a network – whether human, organizational, natural or inanimate – as similarly capable of forming relations and associations. It implies a specific rejection of distinctions between classes of actors and ideational dualisms such as those of geographical scale (local/global), provenance (natural/artificial) or topography (indoor/outdoor) (Murdoch, 1997, p.738).

Translation and inscription

Translation refers to the way actors build networks and mobilize support from human and non-human actors by aligning the interests of other actors with their own. Inscription is the converse of translation by which a use, perspective or interpretation is embodied in another entity (often an object, material or medium). As Latour puts it, the architect's conception

of a lecture hall includes the placement of the podium and chairs. This asserts a localised and non-deterministic authority over our use of these objects. This authority is non-deterministic in that we could simply reject the intended use and do something different (Latour, 2007). In the same way, the intended use of a working railway is inscribed as material culture (station seats, ramps, railings, etc.) in a highly suggestive but non-deterministic way. The idea can be applied to railway ruins in the following way: inscribed meanings and uses fade over time and disuse. Non-human actors (objects) now act on other entities with alternative or competing inscriptions, as well as original/historical inscriptions. These actors in turn translate the new material culture of the railway (a park, a retail space, a museum) for other actors and, if successful, enrol them into the resulting network.

The importance of material culture

Material objects act on other entities to reveal a conceptual organisation of the world, to add coherence and ritual to the activity, and communicate how users can and should use the objects. Material culture is "how a technology/artefact/material object participates in everyday life" (Kien, 2009, p. 29).

In the case a functioning train line, the relations between human and non-human actors are revealed through material culture. A long bench in the middle of a station conveys the act of waiting and the primacy of the train's schedule over the traveller's intentions. This limits their opportunities for dining, writing or other actions. It has no partitions, indicating that the space is to be shared. These forms of use are inscribed into the design of the bench and translated by other human actors, who demonstrate its use. Every human or non-human within the network helps to convey (or, in rare cases, challenge) this cultural meaning.

Similarly, the lack of a consistent material culture can be seen in a train line in ruins. The same bench is inscribed very differently when encountered within an abandoned station. Its uses are less determined as actors with different interests offer competing translations. The weeds and overgrowth may suggest it is a nature site. Signs of unauthorized use may suggest a wide variety of illicit uses. Some will see a museum or a canvas to paint on. Others will see the potential for a restored train station. In the case of a ruin, the prescribed material culture of the original network does not disappear – it survives in competition with new inscriptions and translations by new actors.

Returning to the starting question of why the Beirut-Bekaa line has so far not been repurposed and developed, an ANT analysis implies that we should favor "sticking to description" over an explanatory approach. We need to map the actor-network, while resisting the urge to introduce ideas and theories that are not revealed or implied by this mapping. In other words,

within the network, any explanatory power should be self-explanatory from a complete description of the network, such that the "false dichotomy" between description and explanation becomes another dualism collapsed or rejected by ANT (Latour, 2007, p. 224).

Railway ruins and relational networks

Latour and Murdoch specifically cite the example of a railway line as an urban network that seems to resist categorization as global or local (Latour, 1993; Murdoch, 1998b). A working rail network is a clear example of a stable actor-network, where the human actors all know the appropriate uses of the material actors, and all share the same basic vision and adherence to the rail's purposes, its authority over time (through timetables) and over human movements through its narrow linear spaces. According to Latour, all the interests and understanding of all the actors in a functioning rail network are "aligned in the same direction" (Latour, 1997b, p. 176). Qviström (2012) introduced the idea of a 'network ruin' to describe how the spaces of a stable rail line change relative to other entities in its actor-network. As the line stops running and the shared interests and understandings dissolve, the "spaces of prescription" become "spaces of negotiation," where actors have far more choice and leeway in how they use, represent and transform the other actants in the network (including the objects and spaces) (Qviström, 2012).

Material actors in these spaces of negotiation lose the strength of their inscriptions, and the answer to the question "what is this for?" becomes progressively less clear. The resulting network of actors seems muddled in contrast to the stable actor-network of the working rail line, as actors' translations compete. The once-stable but now "shattered actor-network" continues to exert inertia on the evolving network ruin, so that new uses of the space develop alongside the line's former material culture. "The concept of network ruins is employed to provide a forum for discussions on the intermediate phase, where the importance of incomplete dismantling, delays and the inertia of habits and materiality is acknowledged " (Qviström, 2012, p. 260).

The idea of network ruins existing as an "intermediate phase" between a past stable actor-network and a future stable actor-network suggests that actor-networks move toward stability, rather than continuing to exist in their muddled, unstable state. In fact, Qviström's (2012) case study has the benefit of hindsight: it examines a historical railroad ruin that eventually became a working greenway, and once again a stable actor-network, with new uses clearly inscribed on the space and human actors using them appropriately. Most ANT theorists similarly seem to follow the actors responsible for stable actor-networks, rather than examining the dynamics of networks with competing inscriptions and no dominant material culture.

However, ANT is perhaps even more suited to the examination of indeterminate, unstable, or in-between actor-networks, where it can describe the persistent lack of shared meaning and use. The push-pull dynamic of actors in an unstable network may help describe how different actors pursue different changes (transformation), or resist change (inertia). This in turn may lend insight into why these networks remain unstable, and their uses unresolved.

A mapping of the actor-network on the Beirut-Bekaa line

As ANT theorists suggest, the mapping is taken as a process of real discovery, rather than a way to support a preconceived idea. Limiting the number of actors to examine seems an arbitrary task since, conceptually, nearly anything can be analyzed as an actor, and "actor networks are infinitely extensible" (Jackson, 2015, p. 39). As a result, it is difficult to know where to start when mapping a network of actors. However, taking ANT at face value (as some studies in urbanism have done) suggests that "the configuration of a relationship is what counts - not its nature, function or purpose," and that attempting to characterize a relation or link between actors as oppressive or transactive, for example, would be an interpretive leap not suggested by the logic and topology of the network. Therefore, I first tried to label all the active elements of an urban system, then to identify their roles, and finally to focus on the associations among them (Cvetinovic et al., 2017, p. 142). This process was undertaken with the reflexive acknowledgment of the researcher that even the most basic choices (such as what counts as an entity) are deeply subjective and informed by the researcher's perspective and field study.

Identifying actors

The Beirut-Bekaa line is managed by the Office des Chemins de Fer et des Transports en Commun (OCFTC). This agency reports to the Ministry of Public Works and Transport. It is responsible for the Lebanese railway system, even though this has been totally inoperative for 30 years (Nasreddin 2021, 2021). Various financial and administrative constraints prevent the agency from maintaining this line (or even its 12 bus lines, which are in poor condition). The OCFTC is limited to monitoring legal cases about encroachments on railway land (Osman, 2015, p. 20). Nonetheless, more than 250 employees (administrative and operational staff) work at the OCFTC. This reinforces a conviction already shared by many Lebanese that the OCFTC functions primarily as a reservoir of civil service jobs granted to maintain the loyalty and political support of the politicians who control it.

The encroachers

Encroachments on OCFTC railway properties indicate another set of actors – the encroachers themselves, or those who find illegal and unsanctioned uses for abandoned railway properties. In Beirut, these encroachers sometimes erect informal construction, extending the homes of residents adjacent to the tracks, as well as the less permanent structures and camps for refugees and homeless people. Other encroachers include transient trespassers and companies that place billboards on the properties (Malkoun, 2021). Unlike the OCFTC, which appears to have very little role in actually maintaining the tracks or physically acting on them, encroachers interact with the tracks and the physical spaces of the line every day, despite clear prohibitions. According to the OCFTC's director, the inability of local authorities to actively stop illegal trespassers has prompted the OFTC to file complaints against encroachers with the Public Financial Prosecution office (Ahmaz, 2017). (Figure 2)

Non-human actors

Other, non-human components of the network also need to be taken into account. Apart from the temporary and semi-permanent structures erected by the encroachers, the tracks themselves are in places visible and in other places buried or obscured. Where visible, they show signs of rust and erosion, indicating the presence of other non-human actants (rain, soil, wind, etc.). There are a number of physical barriers to access – such as walls and fences – erected by the OCFTC, as well as warning and no-entry signs. Biological growth (flora and fauna) also thrives in these spaces, in some places so densely that it prevents access (Hindi, 2020). Without further research, it is difficult to identify precisely how these non-human actors affect the human actors in the network. Some of the latter have been attracted and inspired by the overgrown vegetation and neglect (and probably by the "No Trespassing" signs), and a number of art installations and performances have taken place there. Others may be put off by perceived danger or legal prohibitions.

Other important non-human actors, which will not be discussed in detail here, include "quasi-objects" or "tokens" which are not physical entities, but which shape and inform the relations between and among human and non-human entities in an actor-network, such as the laws that formally grant authority to the OCFTC, the regulations specifying how close residents are allowed to build structures, and the complaints and cases brought against encroachers (Latour, 2007, p. 238).

2a. Urban development turns its back on the railway (November 2019)

2b. Overgrowth of vegetation on an urban railway line (Qobayat-Geitaoui district)

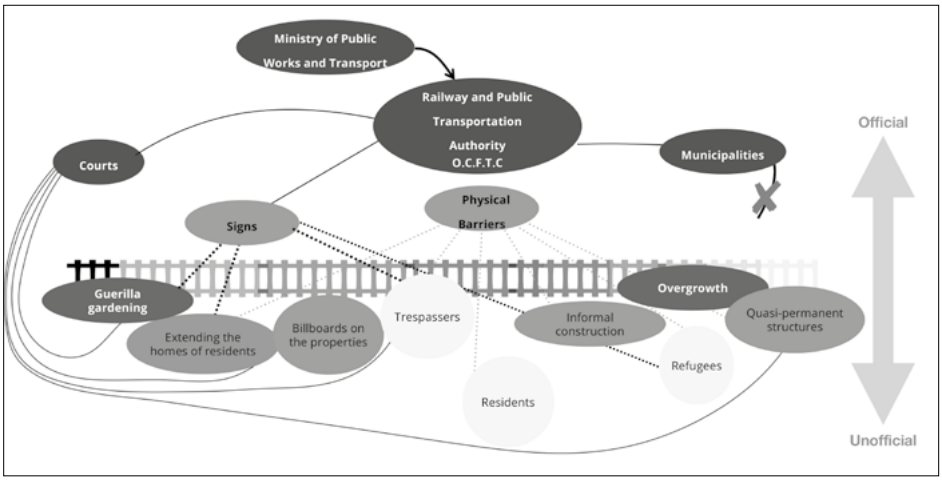
2. The two photos were taken in the Qobayat-Geitaoui district near Mar Mikhael station, Beirut

Photos : by author.

Representation of the network of players for the Beirut-Bekaa line

Figure 3 is one representation of the actor-network along the Beirut section of the Beirut-Bekaa line. It distinguishes between "official" members (actors that retain a part of the material culture of the old railway network and are a source of inertia) and "unofficial" members (which have found a different activity in the ruins of this tattered infrastructure). While the OCFTC is an important and well-connected node in the network, as expected, it is not closely linked (in the sense of the number of links) to the physical tracks. Its only real link with the old railway infrastructure is Mar Mikhael station, where the agency's offices are located. The OCFTC no longer has any direct influence on humans, or on most non-humans (apart from its own signs and fences). Instead, it acts through intermediaries (the courts) to assert ownership. Power under ANT, is manifested by the actors it is used on, "not by those who possess it" (Latour, 1986, p. 268). It is no surprise that OCFTC does not wield much actual power over the actors who are more closely linked to the rail line. However, the ANT mapping exercise was helpful because it challenged a starting assumption: that the OCFTC was a much more central node in the network.

Figure 3 does not do justice to the lesser-known actors, especially in the reduced version adapted for publication in book format. Many groupings and identifications are arbitrary (for example, shouldn't all human actors be in the "trespassers" category?). Further research reveals even more actors: second-tier civil society organizations, businesses, renovation



3. Relations between actors on the Beirut-Bekaa railway line

@ C. El Hage.

proposals, exhibitions, people who throw litter on the line, and political or religious propaganda – all of these can and should be considered actors in the network.

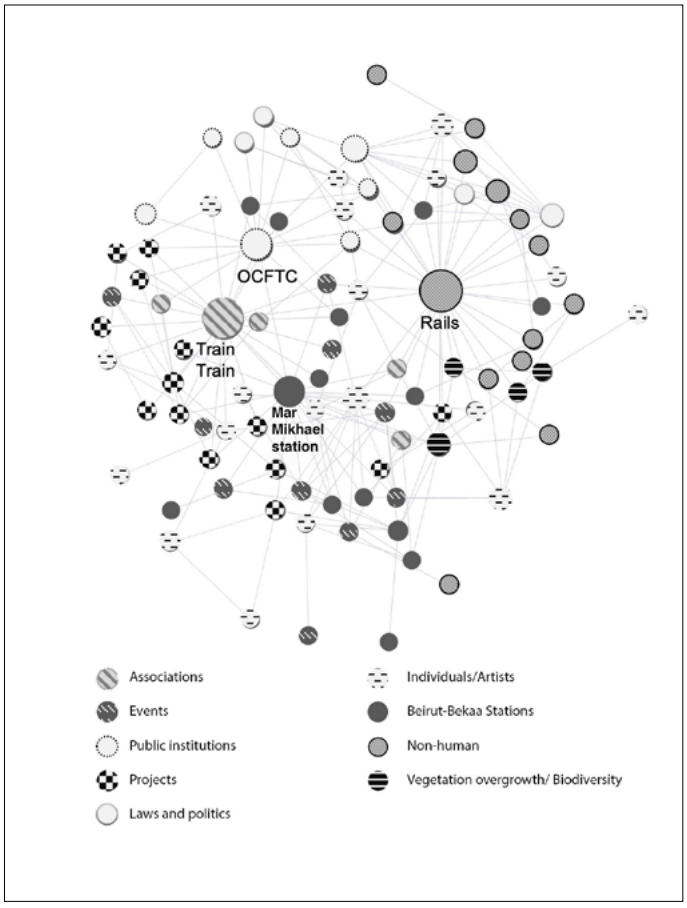
Figure 4 represents an attempt at a more inclusive depiction of the actor-network on the Beirut-Bekaa line. This visualization has less explanatory power than the simplified network of Figure 3, but it does have some heuristic value in revealing important nodes and connections. First, while OCFTC is a large and well-connected node in the network as expected, it is not linked "closely" (in the network sense of number of links away) to the actual tracks. Its only really close link with former train infrastructure is with the Mar Mikhael station, where it has offices. However, we can see that there is a large number of individual actors who favour change (artists, squatters, etc.), but that they are dispersed and unconnected to each other. This aligns with the conception of a network ruin, where the competing translations of material actors generate different types of use. One actor – Train-Train Lebanon – appears as a large node that is well connected with numerous non-humans (infrastructure, locomotives, tracks, stations), and to many human and institutional actors (OCFTC, some of the line's artists, businesses).

Train-Train is a NGO founded in 2005 with the ultimate aim of reviving and restoring the country's railways. Its many missions include promoting the rehabilitation of abandoned railways and stations, preserving Lebanon's railway heritage and raising awareness of the importance of railways and public transportation in Lebanon. Part of their ongoing projects are the design of a museum proposal in the Rayak train station and a preliminary study to propose a master plan for a new public transportation system in Lebanon. On the one hand, the organization advocates the preservation of trains, stations and infrastructures as historical artefacts (even those that don't work). They often hold exhibitions of historical photos on the tracks, and they celebrated the 124 anniversary of the 30-year-defunct railway. On the other hand, it aims to be a partner in translating inherited railway culture into new uses. Train-Train's members include a high proportion of engineers and architects. The organisation has produced a draft masterplan for public transport which, if adopted, would be situated partially on the old line and would require substantial replacement of the same historical equipment and infrastructure they so revere. It therefore invests in the symbolic, historic importance of the railways while revealing the material qualities and strategic opportunities for successfully enrolling allies into its network.

Thus, in our Beirut-Bekaa network, the inertia of the once stable and now fragmented network continues to affect relations between actors, and its persistent material culture competes with emerging uses and activities. This suggests a duality between the forces of inertia and of transformation, in terms of what the space might become or how change is both resisted

and pursued. This dichotomy is suggested by the network itself, which clearly shows tensions between some of the actors that potentially offer transformation and those wishing to maintain the status quo. For instance, if we take Train-Train as an example, the NGO falls into the category of transformational actors.

Figure 4 shows that the latter's power as a transformative force comes from the various allied actors who share the same translation of the infrastructures. The cognitive dissonance is due to the wide variety of actors with different translations of the line and its physical and technical artefacts. One of the translations is the need for a public transport system in Lebanon today, with the result that one of the many actions pursued is the new masterplan. Another translation is the preservation of these ruins so that they can one day be reused as actual



4. Constellation of actors on the Beirut-Bekaa railway

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railway lines. This translation enrolls other actos who are more interested in this intermediate phase of the railways, such as artists and performers. By contrast, the OCFTC falls into the inertial category with some transformative actions more recently, including the approval in September 2022 to transform a part of the outdoor space in the Mar-Mikhael train station into an open public space. This project, led by UN-Habitat Lebanon and funded by the Italian Agency for development, is part of larger efforts to restore the whole neighbourhood after the Beirut blast in August 2020. Therefore, this may result in a step forward toward a partially stabilized network on a small part of the railway.

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In a network ruin, the inertia of the once-stable, now-fragmented network continues to affect relations between the actors, and its lingering material culture competes with emerging uses and activities. This suggests a tension between the forces of inertia and transformation over what the space might become or how change is both resisted and pursued. The network itself exhibits this tension, clearly showing some of actors with transformative potential in tension with actors pursuing the status quo.

Actor-Network Theory is thus a useful tool for understanding how abandoned urban railway structures interact with the human and non-human actors around them, how competing uses compete for predominance, and how these unstable and inchoate actor-networks eventually stabilize (or fail to stabilize). The Beirut-Bekaa line is an illustration of an unstable and evolving actor-network. A map of this network suggests that transformative change is being pursued by some of the actors in this network – notably Train-Train Lebanon – and that others – notably OCFTC – are resisting it.

Yet, at the same time, the network's instability intrinsically makes it a space for negotiation, as shown by the fact that Train-Train and OCFTC have respectively been subject to limited inertial and transformative uses. The idea of a network ruin as a phase "in-between" a past stable network and a future stable network of different uses and actors, suggests that networks of actors evolve towards stability, rather than continuing to exist in their confused and unstable state. Alternatively, it suggests an inherent unease with such indeterminate spaces, that all actors seek to remediate. An open question for this research is whether stable actor-networks are inevitable for urban rail ruins, or whether, as some researchers have suggested, there is value in the vacancy and indeterminacy of a network ruin (Foster, 2014).

Part 4.

Design and Reconnections

Greener, denser station areas? Geodesign and Green Transit Oriented Development in Los Angeles

Halina Veloso e Zarate
and Manuela Triggianese

The concept of sustainable development introduced issues of urban growth and climate change to the domains of geography, urban planning and architecture, becoming major components in research, teaching and practice. The IPCC reports have heightened awareness on climate change and put pressure on the need for action to bring about real-world changes to the built environment. Climatologists note that global urbanisation has greatly influenced the spatial distribution and intensity of carbon emissions and is having a negative impact on climate change. However, they emphasise that well-planned cities with densely populated centres produce numerous benefits if good access to infrastructure and services is guaranteed (energy efficiency and air quality in particular). In this context, Transit Oriented Development becomes a key concept for sustainable urbanization, and Geodesign gains stage as a method to support design decisions in such projects, across domains.

Transit Oriented Development (TOD) emerged in the late 1980s in major American cities as a response to the negative effects of urban sprawl (Cervero and Kockelmann, 1997; Padeiro et al., 2018). This model, strongly supported by international institutions, such as The World Bank (Salat and Ollivier, 2016), was adopted across the world. Site-specific TOD variants adjust to different geographies, engineering cultures, urban policies, and position in the transportation network (Thomas et al., 2018). Regardless of specificities, TOD aims to restructure urban regions around public transport promoting the concentration of dense urban development near public transportation stations (railway, metro, tram, bus). TOD stresses the importance of high-quality spatial and functional planning in urban areas around transport nodes, to configure vibrant transport nodes, where proximity and accessibility by foot or bike help reduce the modal share of private cars and, therefore, CO2 emissions (Bertolini et al., 2012).

When properly developed, these stations meet the three main criteria of sustainability: economic, environmental and social. For example,

mixed-used developments (homes, offices and shops) conduce changes in land and property values and complementarity between functions, contributing to an enhanced quality of living within the node (Triggianese et al., 2018). That benefits economic interests and help to reduce household travel, reducing pollution. Transport nodes connected to public parks and gardens tackles the socio-environmental aspect of sustainability, where greenery has a role in climate-change mitigation (i.e. reducing urban heat island effects) and in the perceived experience of transport users, who can stroll and linger, giving such areas a distinctive identity and their own appeal. However, managing the compatibility between these goals adds to the complexity of the design process and requires the integration of very large volumes of data, pertaining to multiple disciplinary domains.

Data analysis methods contribute to the design of proposals for transport nodes, because they make it possible to deal simultaneously with several interdependent factors, across different scales (macro scale, at territorial level; meso scale at district level; micro scale, at building level). The software boom in the 1990s contributed to the massive shift towards computerisation in design methods (Veloso e Zarate, 2023), as numerous software applications (such as ArcGIS, Catia, Rhinoceros 3D, Grasshopper, Revit, etc.) became accessible to the domains of Architecture and Urban Design (Claypool, 2019). With GIS (Geographic information Systems) and BIM (Building Information Modelling), it is possible to visualise urban and building digital data relevant for station district projects, in two and in three dimensions.

Geodesign refers to a method in which urban and architectural designers use geospatial data analysis to produce reiterated visualisations and formal simulations. The first step in this process is to gather large quantities of input data and then spatialise them (using georeferenced coordinates) in GIS layers and via BIM (in the form of 3D models). This enables greater depth of contextual analysis, and swift shifts in scales. These tools are especially useful for the conceptualization and evaluation of multiple development scenarios, each offering relatively optimal variants between which balances can be sought or compromises made. This is our research field and in this chapter, we present an illustration of the heuristic scope of Geodesign. Following the example of (Lee et al., 2014), we believe that to better understand Geodesign as an integrative method, we must begin with real-world cases and to work directly with practitioners to test the potential and limitations of these tools.

Theoretical background: Geodesign and Green TOD

Thanks to its integrative capacity, Geodesign can be used to simultaneously to analyse contextual data, help create design scenarios and assess their

suitability and performance. It is part of a very rapid development of computer power and the ability to represent data in graphic form, which has been a tool to architects, geographers, town planners, designers, landscape architects. Such data and tools has been giving designers the capacity to work and create impact by means of geovisualisation (Bissell and Fuller 2017).

For example, when there is a need to create or alter the urban form of a district to promote transit oriented development, integrating design and geospatial sciences allows us to study density (the quantity of gross built floor area relative to the area of land available within walking distance of a transit station). Geodesign also allows to measure how this criterion impacts traffic, carbon footprints, etc. (Lee et al., 2014),. Density, depending on the provider, can be secondary data, not raw data. It is constructed from layers of data including cadastral maps of the study area, maps of road and energy networks, drawings of existing and future buildings, and the legally permitted height thresholds. The aim of a density study for TOD is to approach an optimal distribution of built-up space within proximity to the station, from a design-oriented urban modeling approach. That will determine where strategic interventions can take place and leave space for open, green unbuilt area, and help understand what is needed to finance the investment in public transport facilities. Such study also informs if a certain design proposal can ensure sufficient ridership, and hence economic feasibility, in the medium to long term. In sum, these technical tools have a threefold value: help researchers to acquire and analyse complex information for the coordination of urban and transport planning; aid public decision-makers to choose the extent, and location of transport facilities; help traffic managers and public space managers to decide on the form and phasing of redevelopment projects.

As the concept of TOD is multidimensional, its effects in practice can vary, in what refers to urban form, real-estate price, community life, etc. (Ibraeva et al., 2020). This variation depends on the decision-making considering multiple and interdependent factors, that can mean emphasizing one aspect over the others, in search for an optimum mix of design paramenters. Cervero, who largely researches TOD, speaks of different types of "specialised" TOD, referring to the special emphasis given to certain criterion. He introduced Green TOD (Cervero et al., 2017), a station district development strategy focused on reducing energy consumption, emissions, water pollution and waste, and at the same time creating parks and gardens. Cervero also evokes the need to combine an understanding of each of the individual nodes with awareness of the meso and macro scales, to harmonise public rail systems with metropolitan grids and green belts.

Cervero's view is widely supported by more recent work that stresses the importance of a cross-scalar approach to linking the redevelopment of public transport networks with urban planning, configuring polycentric

systems (Mayne et al., 2016 a and b). On a neighbourhood or micro scale, the design principles of Green TOD include strict targets for energy and water consumption and tend to focus on synergies between access to green spaces and access to transport. On the network or macro scale, Green TOD analysis tools should help designers to find innovative solutions to tackling the constraints of urban sites (splits in the urban fabric, heat island problems, extreme urban sprawl, traffic jams, smog, drought and forest fires). Green TOD becomes a suitable framework for the analysis and future development of cities in the 21st century, especially Los Angeles, for its extreme urban sprawl configuration and climate change vulnerability. With the rise in temperature forecast for 2050, Los Angeles will suffer from more extreme and more frequent heatwaves and from a reduction in snow accumulation to replenish local water reserves, while having to accommodate 1.5 million new residents.

Against this challenging backdrop, this chapter attempts to answer the following question: how can Geodesign methods be integrated in the design of sustainable transport nodes that incorporate Green TOD criteria? To answer this question, we present the stages of a case study that is part of a vision project called Sustainable Los Angeles 2050 conducted by the University of California at Los Angeles (UCLA). The aim of the project was to support Los Angeles County's transition towards a target of 100% renewable energy, 100% local water and regeneration of the urban ecosystem by 2050.

Geographical context

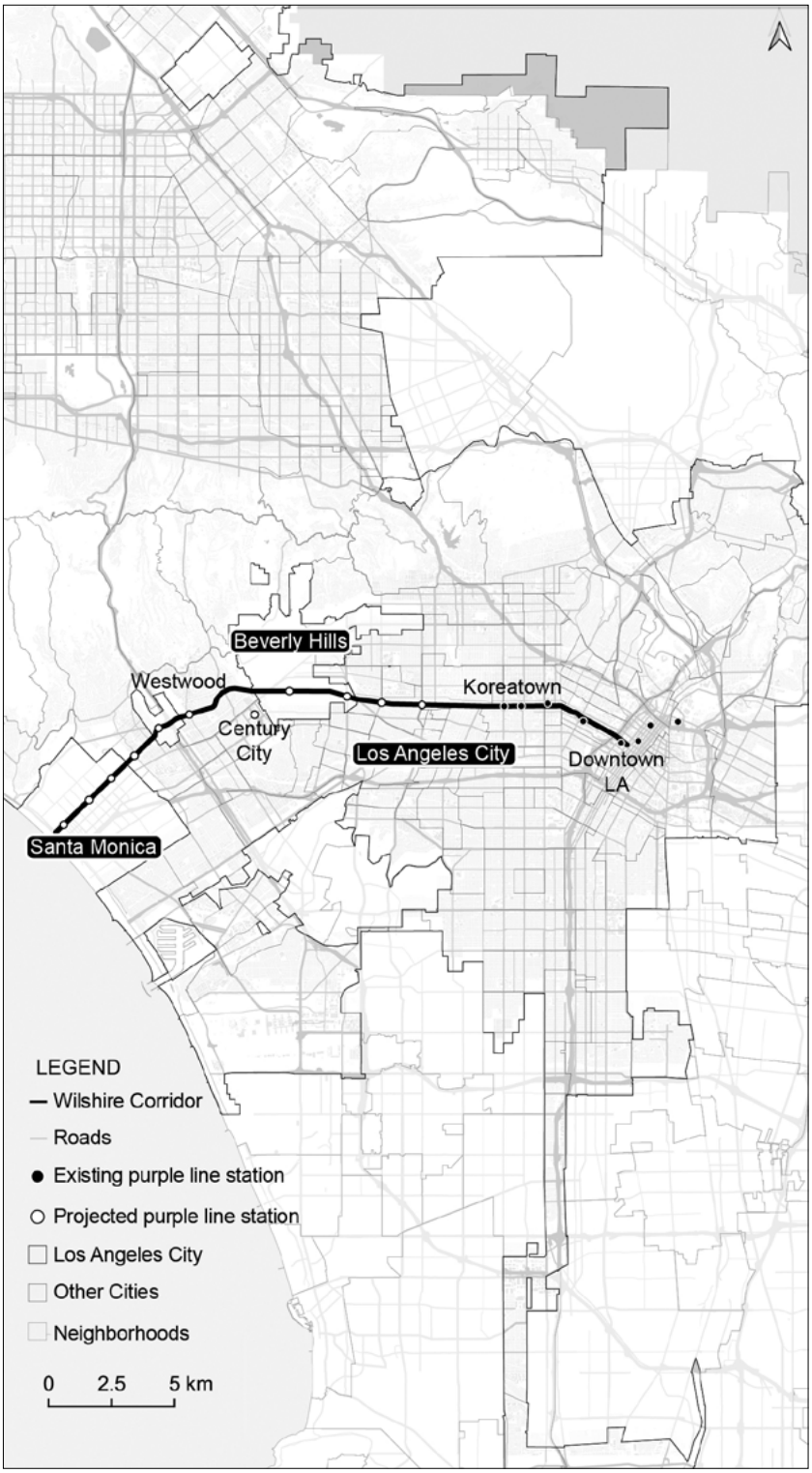
The major US cities have been studied extensively to assess whether forms of TOD are applicable, since from the nineteenth century onwards they were to a large extent structured by very long linear transportation infrastructure axis (Modarres and Dierwechter, 2015) and urban sprawl. In the case of Los Angeles (LA), sprawl led to increased greenhouse gas emissions, smog and water consumption - an evidently unsustainable pattern of living (Cohen 2022). On the 2010s, Los Angeles embarked on a strategic rethink about the revival of its rail system and the regeneration of neighbourhoods along the transport corridors (Ruggieri 2014). Authorities began thinking about the future of their station districts, with a redevelopment plan using Downtown LA as a case to demonstrate rehabilitation that would respect and highlight local history of the station site, improve the passenger experience, make the station a regional hub and also a pleasant public space integrated into its environment, preparing for the arrival of high-speed rail (Ruggieri 2014). Public agencies adopted polices establishing a framework for transit-oriented development, based on High-Quality Transit Areas. In Los Angeles that meant urban areas in proximity to subway (Metro) stations.

By the end of the 2010s, three lines were under construction and expected to serve Los Angeles and adjacent municipalities on the East-west direction: the Gold line, the Expo line and the Purple Line (Riggs and Chamberlain, 2018). The Purple line, along Wilshire Boulevard, is the subject of this chapter's analysis.

Almost 25 kilometres long, Wilshire Boulevard stretches from east to west between 3 cities (Los Angeles, Beverly Hills and Santa Monica) and 18 neighbourhoods (including Downtown Los Angeles, Koreatown, Century City and Westwood) before reaching the beach by the Atlantic Ocean (Figure 1). It represents a metropolitan backbone, alternating between business districts where the tallest office skyscrapers are concentrated, theatre and museum areas, parks, luxurious villas and hotels, from Downtown to Santa Monica Beach. The Purple Line or D line of the subway already runs through some of the eastern districts of lowest income, but for decades the high-income localities in the west refused to accept an extension of this infrastructure. Harris (2017) notes that the public image of transit has changed recently. Local resident groups in the most affluent neighbourhoods, which are also suffering from water and energy restrictions, have become less opposed to the idea of being served by public transport service, which was historically associated with not having a car, and hence with poverty. They have gradually adopted the concepts of Smart Growth and Transit Oriented Development, which are one aspect of this change of mind (Knaap et al., 2022). As a result, public and private sector players have revived the plan to extend the Purple Line westwards.

The study, based on a methodological framework explained below, was carried out by the Now Institute, a partnership between the University of California Los Angeles and Morphosis Architects, a firm that is a pioneer in the application of digital design methods based on big data tools. At the Now Institute, Master's students worked on this project for three consecutive years (2014, 2015 and 2016). The Wilshire Boulevard project here investigated was undertaken in the second year of the partnership under the supervision of two architects and involved twelve students over a one-year period. The project produced TOD scenarios to analysed, discussed and compare possibilities for sustainable urban growth. Two publications are available documenting this work (Mayne et al., 2016 a and b).

For the purposes of this chapter, the authors investigated the digital archive of this project to retrace the data, tools and skills involved in producing the design studies for Wilshire Boulevard, The work was carried out in several stages, starting with the acquisition of geospatial data used and other basic information, reconstructing a digital model of the boulevard and the building of the metro, documenting the energy and water production and consumption, and provision of greenspace in proximity to transit stations. The research was supplemented by consulting meetings with specialists in the urban development of Los Angeles and in urban and transport planning.



1. Map showing the location of Wilshire Boulevard and the Purple Line

@ H. Veloso e Zarate.

Through this investigation, we were able to garner the applicability of Geodesign methods in the different TOD typologies developed for Wilshire Boulevard's proposed nodes.

Construction of the database and findings

Our design process begins at regional scale, looking at the entire urban area and seeking to understand the major transport, housing and environmental challenges facing Los Angeles County. We had to identify the trajectories of urbanisation, changes in road networks, climate zones and urban morphology to obtain information about energy and water consumption and production and identify the sustainability objectives set out in existing government plans. This step enabled us to measure the gap between the current reality and the objective of a 100% sustainable Los Angeles conurbation, specifically to assess the importance of energy and mobility in achieving this objective. It would mean electrifying all forms of transport and significantly increasing the use of public transport, while radically rethinking the form and location of housing and offices. In pursuit of this goal, a 30% improvement in building energy efficiency through technology and typology adjustments (i.e. denser multi-family versus suburban single-family) would reduce demand by 25%, while covering all compatible rooftops in LA County with solar panels would increase the renewable energy supply by 25%. Regarding water, a transition to native landscaping in residential areas would reduce water consumption by 20%, and capturing only one more inch of the County's annual rainfall could result in a 10% increase in the local water supply. For ecosystem and human health, the study showed that the County needs to increase the number of parks by 2.5 to provide access to all nodes in Wilshire Boulevard within walking distance. The effectiveness of all these potential measures would depend on the appropriate distribution and location of urban amenities.

The results show that across the County, the areas with a predominance of single-family houses are those where population density is lowest, while energy and water consumption is highest. They are therefore the area's most remote from Green TOD criteria. Multi-family housing with smaller gardens showed smaller water and energy consumption. Several zones crossed by Wilshire Boulevard match these types of urban form and therefore merited detailed analysis. Numerous thematic maps were produced with the aim of identifying the areas where the imbalance between supply and demand was most critical. Among the indicators relating to water, energy and the environment, the datasets extracted for analysis in this chapter focus on energy consumption from buildings and CO2 emissions related to transport.

In the next steps of the design process, the focus was on the transport nodes in this urban corridor, at the scale of the districts around the station. A very precise characterisation was drawn in the format of 2D maps and 3D models to depict and analyse the morphology of the buildings and roads, the land uses in the various districts, the traffic trajectories and the resource consumption. The Now Institute's proposal was to respond to the predicted increase in the population of Los Angeles by densifying less than 1% of its territory in the form of TODs along the Wilshire corridor, while leaving the rest of the territory unchanged. Of the 20 stops on the Purple Line projected extension, which will link Downtown to the Santa Monica coast in 32 minutes, five areas were identified as having the potential for higher land values and for leveraging the growth of housing, offices and commercial services. Evocative names were proposed for the stations: Ocean Edge City, in Santa Monica; City in the Park, in Century City; Culture Core, in Fairfax; The compact city in Koreatown; and City Stitching linear park, in Downtown Los Angeles. District level geospatial data were used to supplement thematic layers and to export the 3D model from the GIS software to the BIM software (in particular to set the building height standards in each of the districts and manage design interventions). The boundary for the design intervention was established by buffers, centered around key station. These circular boundaries indicated the areas that could be reached in 15 minutes on foot or 5 minutes by bike from each station and framed the detail level needed from the sustainability indicators, to be provided for an area of around 2 square kilometres.

The first sets of data analysed were about living environment and lifestyle, including housing and population density, average water and energy consumption in volume and kilowatts per inhabitant per day, and the ratio of green and open spaces (gardens, parks) in area of green per inhabitant. A second dataset was devoted to the landscape and morphological aspects of these neighbourhoods in the vicinity of public transport. In total, four key criteria (density, water, energy and open space) were used to assess the capacity of each scenario to ensure that the complete system achieves 100% clean energy, 100% locally sourced water and brings accessible greening to the neighbourhood.

In the final stage, the data visualized against the scenarios designed to provide visionary imagery portraying the redensified districts associated with the strengthening of public transportation access in the boulevard. Envisioned from the Santa Monica Beach district, the Ocean Edge City project would accommodate population growth from about 7,500 people per square kilometre (ppl/km2) to around 30,000 ppl/km2, while maintaining frugal water and energy consumption rates and providing around 19 square metres of green and open space per inhabitant. The scenario envisaged for Century City is twice as generous in terms of space per inhabitant but would accommodate an increase in density to around 25,000 ppl/km2

from a level that is almost ten times less than that (by way of comparison, the population density in central Paris is around 21,000 to 25,000 ppl/km2, according to INSEE). In Fairfax, in the neighbourhood of the Los Angeles County Museum of Arts (LACMA), there are currently about 4,000 ppl/km2. This demographic potential could be almost doubled under sustainable conditions of access to water and energy resources, while providing 10 square metres of open green space per inhabitant. Again by comparison, Parisians have access to only 20-30 square metres of green space per inhabitant, whereas Londoners have double. The other station district projects similarly evolve towards more compact urban forms (Koreatown from 19,000 ppl/km2 to 37,000 ppl/km2; Downtown from 15,000 ppl/km2 to 26,000 ppl/km2) or adapt to specific infrastructure constraints. Over in the east, the proposal for the Downtown Los Angeles station area is to cover over the expressway – which currently forms a physical barrier between Downtown and Westlake – and to create a linear park in the form of a green grid across the width of this amenity in order to revitalise the area.

These frugal resource-use targets are achieved in the scenarios by using building design methods that include the installation of specific eco-technological equipment: the available roof surfaces are calculated to confirm the possibility of installing solar panels or wind turbines to produce clean energy, to allow rainwater to be collected and, in some cases, to extend the available areas of green and open space per inhabitant. The outlines of the buildings are drawn digitally, using a combination of mapping and 3D digital modelling to design solutions to the spatial constraints (towers and covered expressways). Streets are inserted in areas that are too densely populated to make the road structure suitable for non-motorised local travel, and construction zones have been created in infill spaces. All in all, when all the sustainability data and objectives considered are considered (Table 1), this corridor could accommodate the 1.5 million additional residents that Los Angeles County anticipates having by 2050, while providing 100% locally sourced water, 100% clean energy and more green spaces, by altering only small proportions of the existing built fabric, namely the neighbourhoods best served by public transport along Wilshire Boulevard.

Using Geodesign, it was possible to form neighbourhoods with distinct morphological and landscape features based on their existing socio-spatial characteristics, without rendering them completely unrecognisable. Some neighbourhoods absorb a larger proportion of demographic growth and become more densely populated, while others are reshaped through a drastic reduction in their consumption of resources. Overall, this outcome was judged acceptable, as each area has its own specific characteristics and spatial potential, which contribute in different ways to achieving Green TOD objectives.

Components	Stage of the design process	Geospatial data integrated into the design process	Objectives associated with the use of this data
Energy	Analysis	Networks: transmission lines, power plants, etc. Emission data and consumption: solar and wind potential, carbon footprint, electricity consumption. Spatiotemporal data: travel time, service areas, walkability	Better understand the context and dimensions related to the sustainability objectives, by working on both the energy efficiency of buildings and emissions linked to transport. Identify opportunities for synergies to meet the characteristics of supply and demand for housing, mobility and services.
	Synthesis	Criteria: position of nodes within the transportation network, node boundary (800-meter radius from the stations), building typologies Urban Planning regulations: height envelope, 3D model of building height, historic preservation areas, legislation on built heritage, natural areas, schools and hospitals.	Establishing the boundary of the study area, defining the maximum densification potential, tracing the non-densifiable land. Creation of densification scenarios within existing contexts, in which population density can be achieved. Construction typologies and valorization of open spaces to generate green energy.
	Assessment	2D maps and 3D model of buildings, netowrks and green spaces Population density, energy consumption	Evaluate whether the design proposal can achieve the goal of 100% clean energy.
Water	Analysis	Drought, rainfall, water flows, water supply aqueducts, water consumption per neighborhood and per sector	Better understand the context and dimensions related to the sustainability objectives, by working on both the water consumption pattern versus the potential for rainwater capture to meet demand. Identify opportunities for synergies to meet the characteristics of supply and demand for housing. (considering lifestyles across the transportation corridor)
	Synthesis	Node boundary area for potential rainwater capture (800-meter radius from the stations), building typologies and rooftop surfaces for rainwater capture, population density and water consumption patterns per district	Définition d'enveloppes bâties aux abords des gares dans lesquelles le niveau de redensification est compatible avec un objectif de consommation d'eau raisonnable.
	Assessment	3D building model, building typologies, population density, rainfall, water consumption, water supply	Manipulation of multiple building typologies and densification scenarios to combine densification, water catchment and supply targets. Assess if the proposed urban form may or may not achieve the goal of 100% water from local resources.

Green Spaces	Analysis	Nature preservation zones, impact of climate change of ecosystem, climate zones, extreme heat days, habitats	Better understand the context and dimensions related to the sustainability objectives, by working on both the provision of green (public and private) per inhabitant, versus the potential for creating new public green spaces to meet the sustainability criteria. Identify opportunities for synergies to meet the characteristics of supply and demand along the network.
	Synthesis	Node boundary area for existing and potential access to green (800-meter radius from the stations), building typologies and rooftop surfaces for potential new green, population density and green per district. Analysis of the distribution of space to supply green on the Wilshire Boulevard area.	Building scenarios to make it compatible densification objectives and increasing the ratio of square meters of green spaces per inhabitant.
	Assessement	3D model, building typologies, population density, green space demand and supply spaces	Assessment of the increase in access to green spaces for city dwellers in terms of: – time distance, – higher environmental and landscape quality of spaces, – ecosystem benefits (air and water quality), – physical and mental health of populations, – built environment attractiveness

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The integration of Geodesign methodologies into the planning and development of Transit Oriented Development (TOD) represents a fruitful method in bridging domains by applying data sciences techniques. Following such methods, progress in Transit Oriented Development relies on the quality of the work involved in collecting and organising documentary sources and data (archives and open-source data); the technical handling of digital tools for geolocation and modelling; the collection of statistics (on consumption per inhabitant and per hectare); and further scenario modelling in greater detail.

Green TOD represents a major shift in this mixed field of research and practice, as it combines the criteria of access to public transport facilities, optimum use of land resources and denser urban development, with environmental objectives such as access to green spaces and frugal use of resources. The Green TOD neighbourhoods that are currently springing up in the heart of American cities incorporate styles and forms of urban planning that represent a transition from the car-centred urbanism that has shaped them for so long. They adopt models borrowed from Asian cities (generating density through high-rise construction) while drawing inspiration from European values (by emphasising the provision of public

space and encouraging a human presence in the streets with facilities and amenities: green spaces, children's play areas, shared zones). Green TOD is also sensitive to the role of public transport in creating local hubs, when combined with intermodal facilities that are not only restricted to the automobile (parking lots), but encompass micro-transit services (Mobility as a Service, MaaS) such as bicycle fleets or self-service electric vehicles like scooters.

Data-oriented Geodesign therefore provides a means to characterise the problems arising from the mismatch between resource demand and supply at different scales. It offers a systematic approach to produce and select different design scenarios, matched to the specific features of the sites and projects at different scales.

It is important to reflect if case study transferable and generalisable. That raises the crucial question of data availability (which is generally increasing, but not always of open access), but also of data management and responsible use. In the initial stages of the process, large numbers of maps were produced to better understand the spatial characteristics of the challenges of sustainability in Los Angeles and how they relate to the reticular organisation of the rail infrastructure. In the end, many of these maps and the information they portrayed were not used in the final micro-scale design phase, especially when constructing the final storytelling. This project is revolutionary in the sense that it has the courage to radically redesign and transform specific parts of the metropolis. Nonetheless, is is shy in that it will not alter the highly unequal social conditions of most of the inhabitants of this sprawling metropolis, structured as it is around a system that is dangerously wasteful of increasingly scarce resources.

The methodological contribution of this study is twofold. On the one hand, there is an emphasis on the importance of integrating great quantities of data in the design process, preferably open source. In this respect, the students' contribution was important because the documentary research and data-science work can be time-consuming. In practice, resource-intensive design processes might be compromised in order to save time. However, we emphasize that cutting on the reiterative analytical character of Geodesign is a mistake: it is in through this method that the initial question is carefully constructed and tested throughout the process, and without it, it would be more difficult to truly measure the challenge of sustainable urbanisation in Los Angeles. On the other hand, it should be noted that emphasizing sustainability aspects must also take greater account of the socio-spatial realities that inform the analysis of the context, shape the morphology of urban development and influence the performance of each neighbourhood scenario in the vicinity of a public transport hub. Finally, we are aware that this study, which navigates from the regional scale to the local scale, does not drop down to the scale of individual buildings and the spaces immediately around

the subway station. This leaves room for future research that can more easily involve communities of current and potential residents and users of these districts, and hence accommodate participatory planning practices and human-centric design practices that account for the perspective of the station user.

The reopening of Italy's sub-Appenine stations explored through an innovative educational experiment

Ramona Quattrini,
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The valorisation of heritage and the regeneration of inner areas and territorial infrastructures are often considered to be unconnected fields, explored by separate disciplines and with different skills. Nonetheless, the potential of regenerating railway lines and reopening rural stations is becoming increasingly important in the development of local public action.

This chapter analyses the conditions for reopening the railway line and stations from Fabriano to Pergola in the Marche region of Italy for purposes of tourism. The project described in this essay is based on collaboration between the Marche Region (in particular the Department of Roads, Infrastructure, Territorial Government, Public Works, Mountain Policies and Inner Areas) and the Università Politecnica delle Marche through a workshop organised by the Department of Architecture in spring 2022 under the aegis of the European RailToLand Project.

The Marche region, in central Italy, is characterised by demographic decline, and was seeking to acquire an operational instrument with which to implement strategies for revitalising the railways. The Università Politecnica delle Marche provided skills and tools in the form of an international workshop organised with almost sixty students from six European countries. The participants worked together – adopting a 'Digital Heritage & Design Thinking' approach based on the use of 3D digital technologies – to explore ways to develop tourist and cultural potential around a railway line and stations reopened in 2021.

The objectives of this essay are twofold: first, to show how the regeneration of two small stations in inner areas, together with the associated technical railway equipment (rails, level crossings, etc.) and all the social and memorial realities connected with this legacy (former railway workers, documentary archives, etc.), can serve to create a tourist destination. Second, to explain how this material was incorporated into an innovative

pedagogical approach centred around action-research on the role of stations and railways in the revitalisation of this rural and mountainous area.

Train transport strategies in the Marche region: the case of the Ancona-Fabriano-Pergola line

Investment in infrastructure represents a great opportunity not only to reduce inequalities between different areas but also to create new jobs and halt depopulation in many inland and outlying areas, as well as to build upon the natural, cultural and entrepreneurial excellence of the Marche.

The Marche 2032 infrastructure plan is based on four key concepts – Sustainability, Safety, Inter-multimodality, Interconnection – plus a strategic goal: to achieve a transition from the current comb structure of regional connections to a more innovative mesh structure.

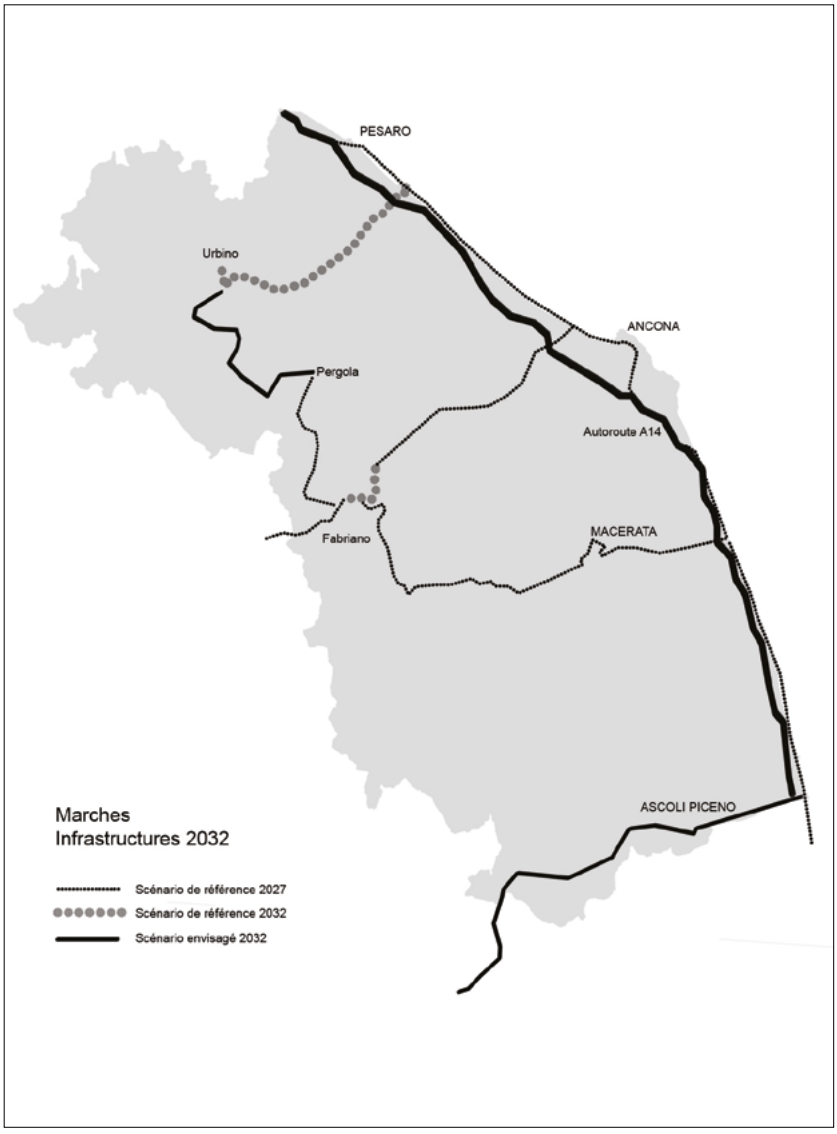
We envisage a region endowed with a sustainable infrastructure, i.e. one that respects the principles of sustainability in the environmental, social and governance (ESG) domains. A network on which it is easy to move around quickly on lines that ensure maximum safety, especially for the most vulnerable travellers. A region that favours intermodality and multimodality, particularly between rail and road, to optimise transport costs and reduce carbon dioxide emissions. A region connected to Italy and Europe via the link with the European TEN-T corridors, both those that run along the north-south route and the new east-west route that we would like to open, corridors which, together, would make the Marche region an interchange for traffic coming from the Far East and heading not just to Northern Europe, but well beyond the Iberian Peninsula.

The strategic "comb to network" plan (Table 1) for both road and rail links is based on strengthening the strategic role of the Marche region as a logistics platform: first, the port of Ancona, in which hundreds of millions of euros are being invested so that it will increasingly be used as the "eastern gateway" to Europe; then, Falconara airport, one of the best-equipped regional airports in Italy, with a runway some 3 km long; and finally, the multimodal transport terminal at Jesi, where an Amazon centre is currently under construction. The three infrastructures are 15 km apart and represent a platform with no equivalent in the Mediterranean basin.

In particular, as far as the railways are concerned, the Marche region's infrastructure plan envisages reinforcing the existing corridors and completing the Marche Rail Ring, in order to offer a robust alternative not only on the coastal route but also on transverse regional roads.

This reinforcement is one of the measures envisioned by the state for the TEN-T corridors, partly using PNRR programme resources. The operations entail extending/retrofitting the Adriatic high-speed network, which will include quadrupling the tracks, as well as modernising the Orte-Falconara

(Rome-Ancona), Civitanova-Macerata-Albacina and Ascoli-Porto d'Ascoli lines. A recent study commissioned in May 2023 by Confindustria Ancona on the impact of the withdrawal of the Adriatic backbone and the implementation of the high-speed rail line, showed that building the infrastructure will cost €39 billion over 10 years and that its impact on GDP will be €82 billion, generating 102,000 full-time jobs.



1. Transport infrastructure on the Marche coast and hinterland

@ M. Ferretti.

The multimodal access system to the Marche Region

Direction	Medium	Infrastructure
Nord - Sud	Railways	**Adriatic Railway,** which wants to be strengthened by a new line for high-capacity and freight traffic, the latter increasing sharply from the ports of Gioia Tauro and Taranto, and which cannot be supported by the existing line, dating from 1863 and destined increasingly to take on the role of surface metro (called "ME.MA., Métro of Marche" for local public transport).
	Route	**Arterial roads:** Motorway A14 and "Autostrada dei Territori Interni", made up of the Pedemontane and Intervallive systems, which link Urbino to Ascoli Piceno and, in Abruzzo, Teramo and the A24 Rome-L'Aquila.
	Cycle paths	**Adriatic cycle route:** "Chioggia-Gargano", of which the Marche region is the national leader.
Est-Overst	Railways	**Railways** Orte- Falconara and the railways that serve local public transport, Ascoli-Porto d'Ascoli, Civitanova Marche-Albacina, Fabriano-Pergola, the latter currently being reopened as a tourist route, in addition to those that should link Ascoli-Piceno without interruption to Urbino, running along the coast to Fano and Pesaro, **closing the Marche rail ring road.**
	Route	**Road links** from the E78 Fano-Grosseto to the SS 4 Salaria, via the Quadrilatero SS 76 Ancona-Perugia and the SS 77 Civitanova Marche-Foligno
	Cycle paths	The **regional cycle routes,** which follow the parallel course of the Marche rivers, are functional for connecting to the Adriatic cycle path along the coast and for safely linking small municipalities, industrial areas, workplaces and centres of interest and services for citizens (schools, sports centres, etc.), as well as increasing the number of tourist routes for two-wheeler enthusiasts
N-S-E-O	Air	**Falconara airport** is one of Italy's best-equipped regional airports, with a runway of around 3 km and a cargo terminal of 1,800 square metres. The main destinations include: Brussels, Cagliari, Catania, Krakow, Düsseldorf, London Stansted, Munich, Olbia, Palermo, Tirana, with recent routes to London Gatwick, Paris, Barcelona, Bucharest and Vienna. These destinations are in addition to the important milestone of the continuity of flights to Milan, Naples and Rome.
	Water	The **Ancona Port** is the headquarters of the Central Adriatic Sea Port Authority. This infrastructure has a draught of around 15 metres and is undergoing major work to reconnect it, through structures such as the Last Mile, to mobility on rubber and iron. The other ports in the region are : Pesaro, Fano, Senigallia, Numana, Civitanova Marche, Porto San Giorgio and S. Benedetto del Tronto.
	Logistics	**Jesi Interport** is located in a strategic position for the Marche logistics platform, between the SS76 and the Orte-Falconara rail route, with links to the European TEN-T corridors. The **Amazon Center** is set to give an extraordinary boost to the volume of goods traffic currently handled by the Marches region.

The aim of the measures is also to reinforce the rail network transversally by restoring the historic Fabriano-Pergola-Urbino-Fano line with a view to reactivating it for commercial traffic. A study carried out in 2022 by Uniontrasporti – a firm that is part of the Chambers of Commerce system – based on the socio-economic effects of infrastructure investment, showed that building the section of the Fabriano-Pergola-Urbino Railway Ring would generate – from spin-offs for the area's economic activities – two euros of value for every one euro invested.

The historic Ancona-Fabriano-Pergola train line, which was reactivated as a tourist attraction in 2021, represents a happy marriage between infrastructure and tourism, a gamble that paid off against the expectations of those who had resigned themselves to the inevitability of its permanent closure. Figure 2 shows a view of the inside of one of the carriages. The line reflects the ambition to pursue a process that had already begun with the reactivation of the Historic Italian Sub-Apennine Train. The idea of taking up the tracks in order to create a cycle path was therefore shelved. We believe that maintaining the rail infrastructure represents a great opportunity for our communities, for young people and for commercial activities in an area impoverished by the infrastructure policies of the past.

Thanks to the support of major Italian rail industry players – RFI, Fondazione FS Italiane and Trenitalia – the section of the Subappennina Italica has been restored, even after the floods in September 2022, and the 1930s carriages totally refurbished. They are pulled by the oldest steam locomotive still in service in Italy, dating from 1907. These carriages carry hundreds of passengers to visit the beauties of our hinterland.

On the regular routes, groups of tourists from Northern Italy, from Lazio and Abruzzo, families with children, as well as train enthusiasts can visit the museums of gilded bronzes in Pergola and paper in Fabriano, the sulphur mines of Ca' Bernardi and the caves at Frasassi, enjoying the beauty of the landscape and culture – unfamiliar to many – and savouring the culinary and wine delights on offer in the region.

The line can also be used for commercial purposes, representing a further step towards the completion of a railway ring linking Urbino, a Unesco World Heritage Site, with Fano, Pesaro and the Romagna region, and to the south with Pergola and Fabriano, continuing without interruption to Civitanova Marche and Porto d'Ascoli, culminating at Ascoli Piceno and the borders of Abruzzo and Lazio. A regional network capable of linking the different parts of the province of Pesaro Urbino to the rest of the region, the Marche region to Italy and Italy to Europe.

2. View of the interior of one of the carriages of the historic train rescued and brought back into service on the Pergola-Fabriano line

Source : Andrea Tessadori for the Erasmus RailToLand project, (no further use allowed)

Creation and decline of the Pergola Fabriano line

The Urbino-Fabriano railway is a line that runs parallel to the coast in the highlands, with many twists and turns. It was built by the Southern Railway Company. According to the initial plans, this infrastructure was to form part of a much larger link called the Italic Sub-Appenine railway that was never completed. This railway was one of the few connections running parallel to the coast, an unusual situation given the infrastructural difficulties of overcoming natural obstacles such as mountains and rivers along the region's north-south axis. The southern part of this line corresponds to the Pergola-Fabriano section (32 km long) that concerns us here.

This section was opened in 1895 (Orazi, 2012), while the connection to Urbino was completed in 1898. Although the Second World War caused considerable damage in the area, the line nevertheless started running again around 1947. Broadly speaking, the fall in traffic was so significant in the 1980s that a special committee was set up to study the possibility of absorbing the operating losses. But the modernisation of the roads, increasing car ownership in the population and, more recently, the closure of local factories (furniture, mechanical engineering) took away the raison d'être of a very frequent service. It was nevertheless maintained, unlike a nearby line, the Fano-Urbino line, which closed in 1987.

Today, Pergola is a small town with a population of just under 6,000, while Fabriano has a population of around 30,000. The small station at Pergola is a passenger building about 1 km outside the village. A freight

building and a passenger building linked by a plain-looking central bay open onto two linked platforms and a footbridge. Around it, the industrial buildings are closed, but the whole area looks well-maintained (grass mown, car park cleaned, benches). This is the work of a voluntary organisation dedicating to preserving local railway history. Fabriano station is larger, on two levels, with 5 platforms. It also seems oversized today, but is still a little more lively (ticket office, waiting room, etc.) and the area, which is closer to the town, was also the source of very active passenger and goods traffic, which required large transhipment areas.

A natural disaster (a landslide following heavy rain) brought traffic to a halt in November 2013. The service was abruptly suspended. However, the line had clearly been under threat since 2000, and various solutions were envisaged: sell it (to whom?); remove the tracks to create a greenway (very expensive); keep them but remove the rolling stock and open a Velorail business (for tourists from the coast). In addition, the question of whether the project should be run by the railways, the local authorities or the Metauro Valley Association, a voluntary organisation set up in 2000 and mainly made up of former railway workers, generated major political conflicts.

Starting in 2016-2017, the Legislative Assembly of the Marche region officially asked Italian Railways to restore the line for tourism, and began looking for sources of funding estimated at between €20 and million. This initiative followed the revival of the Historic Italic Sub-Apennine Train, and entailed a collaboration between the companies Ferrovie - RFI, the Italian Ferrovie dello Stato Foundation and Trenitalia, working together on several aspects of the project: repairing the line, restoring 1930s carriages, recommissioning the oldest steam locomotive still in service in Italy, dating from 1907, and several dozen volunteers to guard the level crossings on each of the tourist routes. The line was reopened in 2021 on the initiative of the Regional Councillor for Infrastructure and Mobility (Image 2). In 2022, the line was recognised as one of Italy's 26 historic railway lines.

The result is that a tourist train now runs from Fabriano to Pergola in summer (Confindustria Marche et al., 2022). It offers day trips for coastal residents and tourists. It publicises the local agri-food businesses (because passengers get to taste a range of wine, cheese and charcuterie specialities in the half-hour it takes to get from one station to the next). Pergola station has been converted into a railway museum with the support of community networks. Between the outward journey to Pergola and the return to Fabriano, groups have time to visit museums and other nearby points of interest. Pergola is a town of Roman origin with a population of around 5,800, with a rich history and culture, and is notably home to the famous gilded bronzes dating back to 23 BCE.

How research and education can support the rebirth of railways and stations in inner areas

The research and teaching activities presented in this chapter were conducted in the Digital Heritage & Design Thinking workshop (Quattrini et al., 2023) developed as part of the "RailToLand – Collective ideation platform on innovative challenges for communicating European Cultural Landscapes by train" project (Quattrini et al., 2021),

The aim of the workshop was to analyse the resources of the natural and cultural landscape as seen from the railway, including Pergola station, and to produce virtual content that potential visitors can explore and raise the profile of this railway revival operation. Information technologies and digital facsimiles were among the innovative features of the workshop: an augmented reality site was installed in the small Pergola station, allowing visitors to view the flow of images filmed from trains and stations. The students both participated in the production of this content, using laser scanners and drones to digitise various heritage objects, and themselves enjoyed experiencing the images.

The workshop experimented with collaborative approaches to design methods through a design thinking process (Brown 2008), consisting of several phases: data collection with field research (discovery), then data processing (interpretation), followed by dialogue between researchers and designers in the project design phase (ideation), leading in to experiments with visualisation techniques and culminating with the presentation of the results. Throughout the design thinking process, a cross-scale approach to the project was applied in order to align the scale of the building (Pergola station) with the scale of the surrounding area. Attention was also paid to the link between the production of this visual content and the narrative that emerges from it, which highlights the existing socio-economic and cultural context. The aim was to avoid arriving at ideas and solutions that were far removed from the needs and possibilities of the site, and also to avoid encroaching on what had already been put in place by the authorities, but rather seeking to improve on and support it in the pursuit of their general goals.

Part of the workshop focused on showing the potential of tourist trains and stations. The students identified areas of historical and cultural significance along the route, using both maps and aerial photographs. The train experience improved their understanding of the geomorphological characteristics and spatial features of the area, but also emphasised sensory and perceptual learning. Travelling by train provides a unique sensory experience, conveyed by the sound inside the train and the smells of the environment, while the perception of space and landscape is also enhanced by the slowness of the historic trains.

The workshop adopted an interdisciplinary approach: experts in digital cultural heritage and in representation, together with specialists in architectural, urban and landscape design, devised an innovative method of studying. The programme included conventional educational activities, such as lectures on the digitisation of cultural heritage and landscape, railway regeneration practices and landscape features along the lines. The approach had strong multi-disciplinary elements, as skills in the heritage digitisation were linked to the need to imagine and design spaces and buildings. These tools could be used with communities and stakeholders to discuss future visions for their territories (Ferretti et al., 2022).

Results of the innovation workshop

The workshop not only provided content to help structure the virtual tourism elements and thus maintain the appeal of this new rail service. It also generated ideas on a theme of great interest to the academic participants in the workshop: the redevelopment of the travel model for the entire area of the so-called Appennino Basso Pesarese Anconetano (APBA).

This rural, hilly area of the Marche region is a pilot site in Italy's spatial planning policy, and more specifically in the Italian strategy for inner areas (Barca et al., 2014). The objective of this strategy, initiated by the Italian Ministry for Territorial Cohesion in 2014, is to test the ability of inner areas to undo processes of marginalisation, depopulation and economic decline through, among other tools, a new approach to mobility (Ferretti et al., 2022). With its difficulties of access and lack of public transport, the vulnerability of its road networks to landslides, and a morphology characterised by river valleys running perpendicular to the coast, the sub-Appenine region is a textbook case for accessibility problems and solutions.

On the problems side, the Fabriano-Pergola line and in particular the stations are sites that clearly demonstrate how difficult mobility conditions are currently creating difficulties around social and territorial justice and equal opportunities. On the solutions side, these connections will be pivotal in restructuring public transport, meeting regional targets for reducing greenhouse gas emissions and thus mitigating the effects of climate change. The Italian government's pilot site is part of the EU's Rural Vision 2040, an initiative launched in June 2021, which recognises the strategic importance of improving rural mobility and emphasises the need to set up multimodal transport systems: stations and mobility systems around which shared mobility services – cycle parking facilities and good walking infrastructure (pavements, clear signposting, lighting) – can be provided. This document encourages smart mobility solutions (digital car-sharing

platforms, real-time public transport information systems, real-time route mapping).

In keeping with these guidelines, the entire rail system, and in particular the line in question, are thus part of the Marche Regional Plan for Sustainable Infrastructure and Mobility, a strategic document that aims to improve the region's accessibility and connectivity by linking it with multimodal rail and road hubs connected to cycling and pedestrian infrastructures (Marche Region, 2023). This determination is shared by the civil society organisations: we emphasise the importance of community structures in advocating for abandoned lines and for investment to make tourist trains possible, as well as their involvement in the railway museum at Pergola. Today, the purpose of the "Civitanova Marche - Albacina" project is to reimagine this rail network, which almost disappeared, as a future aboveground metro with new stops. Following on from the Pergola model, other former railway stations could be refurbished to become showcases for local produce and venues for cultural events and attractions. Residents also envisage that this coastal railway line and its backcountry sections could be used for freight, in particular waste collection.

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Built at the end of the 19th century, secondary rail networks represented a very important connection for the interior of the Marche region. Travelling along contour lines and over steep terrain, they linked villages and small towns and served local micro-economies. Subsequently, many such networks were abandoned in every Italian region, as was also the case in Spain (Ravagnan et al., 2021). When these networks are downgraded, even partially, the territory around them also faces abandonment, because they are "linked to the events of the place, involved with the individual biographies of the sites, connected with other artefacts... Their decommissioning is therefore no longer just a matter of transport... but, through a knock-on effect, influences fragments of territory that have themselves fallen into decline" (Andriani, 2016, p. 13).

However, over the last twenty years, the mindset has changed. While these small railways used to be a blight on the region because of their slowness and the discomfort of travel, they are now seen as an economic resource, as a means of providing access to exceptional views and landscapes. They are perceived as an opportunity for the regeneration and transformation of the whole region. The plan to revive tourism was supported by the local population because it presented an escape from the rail isolation that has been a painful experience over the previous decade. For local people and the rural area as a whole, this line represents a first step towards economic recovery, a physical reconnection with the rest of the Marche, the rest of Italy and Europe, and also an opportunity to

introduce a model of sustainable mobility that is more prevalent in Italy's major cities than in this mountainous area.

The workshop[1] was held at a point when the prospect of reviving infrastructure as a tourist resource came together with ideas about the wider resource potential of the line and the stations within the context of new public policies for sustainable mobility. In harmony with these policies, the small Fabriano-Pergola line represents an approach to reviving travel infrastructure within the framework of a regional strategy based on sustainable mobility, circularity and the integration of culture, tourism and quality of rural life. This workshop had a big technological and digital component, but the work was ultimately as much about identifying existing heritage resources as it was about inventing new solutions. One of the workshop's operational outcomes was a proposal to reclaim the former agrarian consortium building, now abandoned, opposite Pergola station, in order to develop an innovative intermodal hub that could be accredited by the Italian government as a laboratory facility in the Appennino Basso Pesarese Anconetano area. This would open up access to funds for facilities that are still all too rare in rural areas, such as EV charging points.

The analysis of the station building and the consortium's structures highlighted the cultural and historical value of the objects and the strategic position of the station in relation to the railway line and the regional hinterland, as well as the decline in the area caused by the abandoned structures. In line with European guidelines and the strategies implemented at regional and local level, therefore, the proposal focuses on the intermodal potential of the structure, its ability to meet not only the needs of tourists but also, in a medium- to long-term perspective, those of the region's resident community. In transcalar terms, the project also presupposes contributions from a whole series of participants, not just institutional actors, but also investors and private operators in the field of sustainable mobility, as well as community and local actors to handle aspects such as overseeing and enhancing the positive impact of this infrastructure on the area.

In addition, the objective of the proposal is to improve the region's rail infrastructure and, more broadly, its mobility system, as a starting point for attracting more investment. This in turn will bring further benefits to the area in terms of holistic approaches, circularity and resilience, through which the sub-Appennine railway will become an opportunity for experimentation and innovation for the inner area via the encounter between a new spatiality, new technologies and new experiences.

1. The design workshop was coordinated by Maddalena Ferretti, and both teachers and students participated in the "Pergola Hub" group, following a peer-to-peer learning approach. Vanessa Perez (UGE); Francesco Di Stefano (UNIVPM); Chiara Chioni (UNITN); Agathe Daniel (UGE); Jorge Povo (UPM); José Roca (CCG); Marco Genovese (TRENITALIA).

Conclusion

Nacima Baron,
Nils Le Bot and Pauline Detavernier

The aim of this book has been to break down the barriers between geographical disciplines in two ways. Internal decompartmentalisation: the study of railway stations seems to be the sole domain of specialists in transport geography and we have tried to show the potential that their analysis can offer to other specialisms. External decompartmentalisation: we have tried to show that these network places open up new possibilities for links between the human and social sciences and the environmental sciences and technologies.

To do this, we have not hesitated to manipulate all the facets of an object that is inherently multifaceted. We have alternately considered stations as built objects and as socio-technical processes. We have moved from approaches that emphasise the material and mental resources that this built object affords, and have incorporated ideas about design practices and the experiences of station users. We have also chosen to work from two distinct perspectives. On the one hand, considering the ecological railway station as an end of knowledge in itself (thus seeking a way to know it more completely in the expression of its forms and functions). To this end, we wanted to enlist young geography researchers and engineers (and others not so young) to show the abundance of work going into building and testing the necessary conceptual and methodological tools. On the other hand, our effort can be seen as an applied research project that seeks to present the station as a heuristic tool for getting inside the heads of particular actors in a transport industry that is in the process of going green. Once again, it is not our intention to evaluate eco-technological transition-related discourses and processes through stations (energy, post-carbon, ecology). However, our work emphasises the ways in which these stations act as seismographs and indicators of these multiple transitions and transformations, in the face of the major upheavals to come.

How far we've gone: the conditions and limitations of an extended station ecology

The aim of this book is to turn a constructive and critical eye on the debate about the emergence of railway ecology. This is by no means a new discipline that we want to see emerge out of nothing. It is an already established branch of ecology that has come a long way, but which could benefit from being more widely applied than it is today. Originally, railway infrastructure and ecology emerged in the same first half of the 19th century. They owe each other much more than one might think. In Europe, for example, the construction of lines and stations required new efforts to understand geological and topographical features. Private companies embarking on colossal public works projects needed data on geography, geology, hydrology, local climate and so on. And conversely, by excavating trenches, railways contributed to progress in knowledge: geologists followed the train to find answers to questions about the history of the world that they did not know how to answer.

Since then, railway ecology has developed mainly as an applied science that studies the reciprocal effects between infrastructure and ecosystems. It is concerned, for example, with ways of limiting the risks to both trains and animals associated with the movements of large fauna. Or it models the factors and then maps the options for designing a new bunch of lines that has to cross areas of high environmental value. Another piece of this knowledge is rooted in the origins of railway technology and in the foundations of landscape thinking, which links botanical knowledge with aesthetic ambition. Here, railway ecology is both a science and a sometimes experimental practice, which is implemented to harmonise with specific flora and with landscape and cultural traditions (Japan, United States, Europe) in order to situate stations in an attractive setting, to creates appealing compositions of vegetation and panoramas for passengers to see from the train window or to stabilise the slopes of railway embankments.

These perspectives are in no way neglected or underestimated. We are even alert to their echoes in contemporary debates (as shown in the chapter devoted to railway forests). However, our ambition has been to expand this discipline by more precisely defining two linked processes: the greening of infrastructures and the infrastructuring of objects and flows from the natural world in and through stations.

By the greening of stations, we mean two things. On the one hand, the introduction of eco-technological artefacts designed to mitigate the infrastructure's impact on the environment and to optimise or circularise the consumption of material and energy resources. On the other hand, we have sought to appreciate the greening of the station design professions by showing how anthropocene thinking presents railway engineers with the idea of the railways owing an ecological debt, for which they take res-

ponsibility and which leads them to behave in a sometimes schizophrenic way. It is an obligation of modesty and exemplarity, but also a vision of their community as possibly in the vanguard of industrial ecology. We also hope to have contributed to thinking about the way in which sometimes catastrophist environmental discourses are reconfiguring the systems (legal, political, financial, digital, social) within which these professionals are building themselves a new space for thought and action.

We have also emphasised that this learning process is based on the global circulation of eco-station concepts and models, as well as on very practical, real-world management experiences (such as dealing with heatwaves, which are becoming increasingly troublesome for station operators in summertime). This idea of "greening" is embedded in ecological planning agendas that are clearly not restricted to station professionals: these agendas are backed by public authorities, supported by legislative and regulatory changes, and come with a swarm of normative flows (certifications, labels) that drive – or conversely lock in – more empirical and bottom-up practices.

Stations are infrastructures, i.e. parts of systems linked to other systems. Institutions and social, technical, political and institutional systems create infrastructures, while infrastructures – as we have tried to show through the example of greening – create capacities or exploit political, economic, ecological and social opportunities. Isn't the blog for disgruntled users of Paris suburban trains called "train de vie" (life train)? Yes, infrastructures are human and also living things in that they embody the relationship between city dwellers and the artefacts that shape their lives and which they in turn shape. In addition, our work has projected the notion of infrastructuring backwards and forwards in time. Indeed, the ecological challenges coincide with a "wall of re-engagement" and call for connection between the repair and maintenance of legacy stations, the testing of new forms and the production of a new type of station in the future.

To go further

It is clear that the contributors to this book have focused more on railway professionals than on train users. This does not mean that participatory surveys have not been conducted, or that interviews and observations have not been carried out with people who use stations (railway workers, homeless people, etc.). However, we would like themes of this book to be extended to user-citizens, and we envisage two pathways of development for this work.

First, railway stations, even when endowed with many ecological services, are often designed in a vacuum by political decision-makers, investors, planners and architectural engineers. And second, this book could be extended to take a more direct look at the idea of the ecological

station from the point of view of infrastructural citizenship. Posed from the outset as a question of political ecology, this approach should focus on how citizen (and taxpayer) access to public infrastructure is conceived, and how the use they make of it affects and is affected by their identity and their practices as citizens. From this perspective, users are no longer treated as consumers of green stations. Instead, the question becomes how – in neighbourhoods sometimes deprived of the resources to cope with climate change – the station can represent a common asset around which residents can formulate new demands or organise themselves to produce the services they lack. Involving citizens in the practice of metabolic flow management also transforms their subjective relationships from consumers to 'prosumers'. From an empirical perspective, this line of research can give new impetus to thinking about greening rooted in protests, conflicts and controversies. In theoretical terms, this research would benefit from a closer association between stations in the Global North and South, since the urban and infrastructure systems of emerging countries appear to be less locked into dependency processes: fewer safety standards, populations accustomed to a form of infrastructural precarity and under-performance (speed, timetables, comfort, etc.). They have a less conservative relationship with the built (or planted) heritage and are constantly rearranging what is "already there"…

The second direction along which these ideas could be pursued is to complete the other half of the spectrum of experience of transport infrastructures in the era of climate change with a more intimate, more corporeal and more sensory ecology. This research could pursue theme relating to ambiences and atmospheres and should leave room for expression of the feelings of users and passengers. We should develop strategies for observing and interpreting behaviour and verbal and non-verbal interactions, and step up the capture and measurement of sensory and physiological data in an attempt to reconstruct the individual and collective physiology of these places. Moreover, we will not be able to establish this ecology without once again embracing the aesthetic and artistic dimensions that are so abundant in railway stations. It is not just a matter – as has already been mentioned here and there – of considering art simply as one of the contents that the station contains. Nor – or at least not only – is it a question of wielding art as a research method and transmission tool for greening stations and the mobile life that goes with them. Using a station is above all about knowing and having to wait, something so alien in our frenetic world. It means being somewhere on earth and looking around. It is the whole purpose of reconciling mobility with ecology: perhaps we need to start again from that still distinct moment, that epiphany.

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‘Architecture of Mobility’ (stations) as a testing ground. The approach aligns architectural design with systemic shifts in sustainability, digital transformation, and social innovation, ensuring solutions are impactful and scalable to address real-world challenges and needs. She is as an architect and she holds the international PhD Villard d’Honnecourt doctorate, a collaboration between TU Delft, IUAV, ETSAM and ENSA Paris-Belleville. She worked as Marie Curie research fellow at the Beijing Technical University and Postdoc at AMS Institute. She is principal investigator of the NWO research project Walk-In co-creation (on sub-urban stations) and the author of numerous international publications.

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* AREP : Architecture, Recherche, Engagement post-carbone.

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Contents

Part 4. Design and Reconnections

Colophon

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If railway stations remain urban symbols and legacies of a prestigious past, they must now adapt to global changes and transitions. The book highlights theoretically and empirically the paradigm shift towards the ecologisation of rail stations and their neighborhoods. It explores and explains the various technical processes involved in this perspective (circular reuse of construction materials, environmental and landscape integration, energy sobriety and, climate adaptation, etc.). It shows how these processes associate railway regeneration with territorial and social promises and progresses.

The twenty-one experts brought together in this book deploy critical approaches and international perspectives far beyond green-advocacy or greenwashing. They view the railway station as a lens to engage in trans-disciplinarity and call for a rearticulation of naturalistic, thermodynamic, architectural, social and political perspectives in the design and policy literature on railway nodes and places. The book invites the user, as well as the inhabitant and the citizen, to address with a new perspective a key part of urban socio-enviro-technical transitions. It offers a vision of its long way forward, with its processualities, complexities, but also shapes recent achievements and future potentials.

After having graduated at the École Normale Supérieure in geography and urban planning, Nacima Baron teaches at University Eiffel and does her research as senior member of the Institut universitaire de France. She studies combines an interest in urban flows and an sociotechnical questioning of railway infrastructure regeneration trends.

Pauline Detavernier holds a PhD in Paris Malaquais School of Architecture. She is a specialist of the design of pedestrian pathways in train stations and, more broadly, on the practice of walking in places of mobility. She currently works as an R&D project director at PCA-Stream and teaches at Paris Val-de-Seine School of Architecture.

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